OILS

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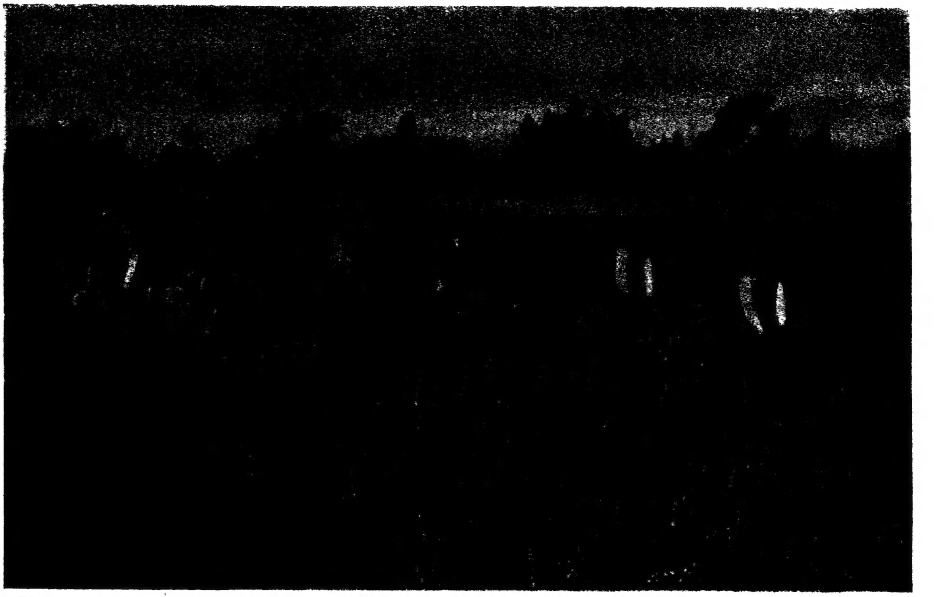

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CUTTING LAVENDER

PITMAN'S COMMON COMMODITIES
AND INDUSTRIES

OILS

ANIMAL, VEGETABLE, ESSENTIAL, AND MINERAL

BY

C. AINSWORTH MITCHELL

LONDON : SIR ISAAC PITMAN & SONS, LTD.
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PREFATORY NOTE TO THE SECOND EDITION

THE principal advances in the oil industries during the last five years have been the development of the manufacture of hardened fats from oils, and the production of a petroleum spirit by the compression of natural gas.

An outline of the processes involved in these developments has been given.

The table of imports and exports of oils and fats has also been extended so as to include the most recent returns published by the Board of Trade.

C. A. M.

January, 1916.

PREFACE

IN the following pages I have endeavoured to tell in language free from technicalities the story of the origin, methods of preparation, and uses of that immense class of commercial products to which the name of "oil" may be applied.

It will readily be understood that the ground to be covered was so extensive, that it was necessary to dwell chiefly upon the most typical products in each class,

and to make little or no mention of some of the less common substances, such as the little known vegetable fats from Central Africa, which have as yet chiefly a scientific interest.

With regard to the section on Essential Oils my best thanks are due to Mr. E. Parry, F.I.C. for permission to make use of certain details of information given in his standard work on the subject; and also to Messrs. Schimmel and Co., the well-known distillers of volatile oils, for their kindness in lending illustrations of their rose fields and distillation plant near Leipsic.

In writing the section upon Mineral Oils it was necessary to consult numerous scientific publications and works upon the subject, and in particular I should like to acknowledge my indebtedness for information upon historical and manufacturing details to the writers of the following books:—*Petroleum and its Production*, by Sir B. Redwood; *Treatise on Mineral Oils*, by Mr. J. J. Redwood; *Le Pétrole*, by M. de Fonvielle; *The Story of Oil*, by Dr. Tower; and *The Technology of Petroleum*, by MM. Neuburger and Noalhat.

The illustrations in this part of the book are specially reproduced from photographs kindly supplied by the Baku Russian Petroleum Oil Company, to whom also I tender my thanks.

C. AINSWORTH MITCHELL.

WHITE COTTAGE,
AMERSHAM COMMON,
BUCKS.

CONTENTS

LIST OF ILLUSTRATIONS

OILS

PART I

FIXED OILS, FATS AND WAXES

Nature of Fixed Oils.—The term "fixed oil" is employed as a convenient description for distinguishing between ordinary vegetable and animal oils and fats, and the volatile mineral and essential oils. Strictly speaking there is no sharp distinction between fats and oils, the former being reduced to an oily condition by heating and the latter converted into solid fats when sufficiently chilled.

Apart from this, they are for the most part of similar chemical composition, consisting in the main of compounds of glycerin with various acids known as "fatty acids" from the fact that they were first isolated from fats.

Thus, for example, lard consists of compounds of glycerin (known as glycerides) with solid fatty acids (stearic acid, palmitic acid), and with a smaller proportion of liquid fatty acids (oleic and linolic acids). In tallow, there is a larger proportion of the hard stearic acid, less palmitic acid, and still less of the liquid fatty acids. Again, in the case of olive oil, the chief constituent is the liquid fatty acid, oleic acid, whilst the solid fatty acids are only present to a relatively small extent. In other oils, other liquid fatty acids such as linolic and linolenic acids are present, while in other solid fats, especially those of the vegetable kingdom, glycerides of

other solid fatty acids are important constituents. The waxes, of which beeswax may be regarded as typical, differ from the ordinary oils and fats, in consisting of compounds of various fatty acids, with alcohols other than glycerin.

It is chiefly by means of the separation and properties of these various fatty acids and their compounds that it is possible to distinguish between different oils and fats.

The fixed oils and fats have many properties in common. Thus, they cannot be evaporated (like essential oils) at the ordinary atmospheric pressure without decomposition, and when heated they do not give off inflammable vapours until a temperature sufficient to decompose them is reached.

Saponification.—When boiled with a solution of potash or soda, oils and fats are slowly decomposed or saponified, and form soaps, the nature of which will depend upon the alkali used and the kind of oil or fat. For instance, a very hard soap is obtained from tallow and from earthnut oil, whereas cocoanut fat yields a soft soap, which is readily soluble even in hard waters, and is therefore used as the basis of the so-called "marine soaps," which will give a lather with sea-water.

Drying Properties.—Vegetable oils differ to a pronounced extent from one another in the manner in which they form a dry skin when exposed to the air in a thin film, these differences depending chiefly upon the nature of the fatty acids. Thus, linseed oil dries very rapidly and is therefore regarded as the type of *drying oils;* cotton seed does eventually form a dry film, but the process is so slow that, together with oils of similar drying capacity, it is classified in a group termed *semi-drying oils;* whilst the third class, or *non-drying oils*, belong to those, which, like olive and almond oils,

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SELF-CONTAINED BELT-DRIVEN EDGE STONES

remain practically unaltered in consistency after long exposure to the air.

Some of the animal products also possess drying properties, and this is particularly the case with the oil of certain wild birds such as the blackcock.

Classification.—The vegetable oils may be considered under the following groups based upon the foregoing differences: (1) Non-drying oils; (2) Semi-drying oils; (3) Drying oils; (4) Vegetable fats. The animal oils and fats, again, are conveniently classified in the following groups: (1) Solid body fats (tallow and lard group); (2) Milk fats (butters); (3) Animal oils; (4) Fish and marine animal oils. The waxes (animal and vegetable) form a third main group. Naturally, as in all classifications of natural products, these groups overlap, and certain oils might be placed equally well in more than one group.

I. VEGETABLE OILS

Extraction.—The methods of separating the oils from seeds or fruits depend partly upon the size, hardness and other properties of the fruit, etc., and partly upon the consistency of the oil and the uses for which it is intended.

The different methods used for the separation depends upon (1) Expression, in which the seeds are crushed and oil expressed; and (2) Extraction, in which the oil is dissolved out by means of a suitable solvent which is subsequently evaporated, leaving the extracted oil as a residue.

Expression.—The methods of expression range from the primitive hand presses used by the natives in West Africa, India and elsewhere, to the modern highly effective apparatus now employed for the expression of the oil from the seeds of the cotton plant (see p. 16).

Other machines are employed in preparing the crude material for extraction or expression. Thus cotton seed and earth nuts need decorticating, while linseed and rape-seed need screening and cleaning, and cocoanuts are broken up in a special disintegrating apparatus. Prior to pressing, large seeds or bulky material are ground up in what is known as an " edge-runner " seed mill, in which two vertical stones are made to revolve in a circular trough. The material is then transferred to seed crushers, containing one or more series of rollers, which may be grooved (for palm kernels or earthnuts) or smooth for breaking up linseed seed or cocoanut pulp (coprah). In the case of small seeds the preliminary grinding is unnecessary. The material, thus reduced to a pulp or meal, is next heated in large cylinders known as " kettles," through which pass steam pipes, and is then delivered to the press. Or in the case of certain substances rich in oil this heating may be omitted, since the oil-cells can be ruptured without the aid of heat. The seed-meal, with or without previous heating, is received in press-cloths, consisting of closely-woven cotton cloth, enveloped in horsehair cloths, and is subjected to a preliminary squeezing to mould it into " cakes." These, still wrapped in the cloths, are next packed between the pressing plates of a hydraulic press and submitted to heavy pressure, so that the oil exudes, and passes by way of grooves or holes in the plates to the bottom of the press, whence it can be drawn off into suitable tanks placed at a lower level. As a rule, the pressing is repeated once or twice, the material being first broken up each time in a cake-breaking machine or in the edge-runner mill.

In certain types of presses circular iron boxes, the inner lining of which is perforated with holes, take the place of the plates and cloths, and these have the

advantage of giving a more uniform pressure to the material, and consequently a larger yield of oil.

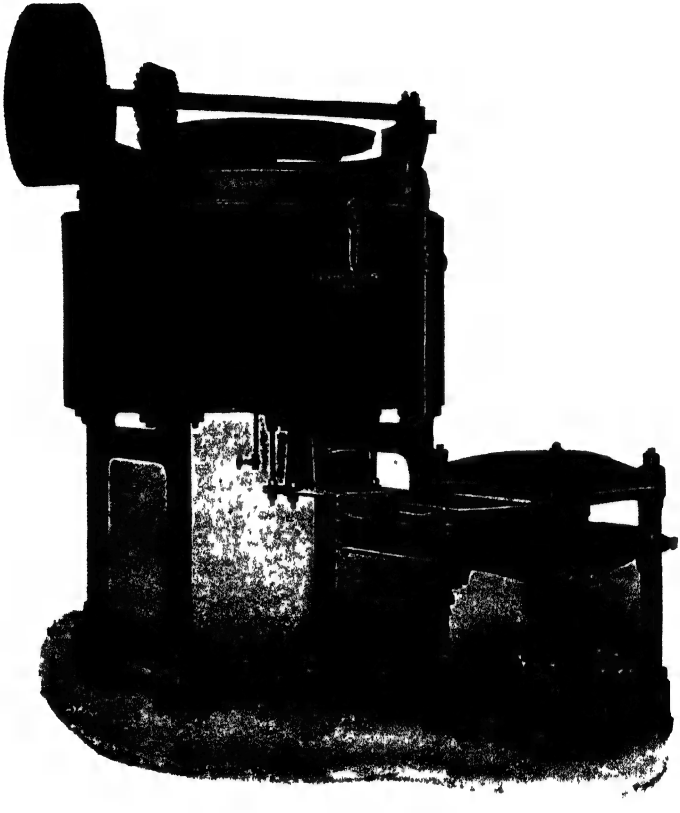
Oil of the first pressing is superior to that obtained in the second and third pressings, the latter containing a larger proportion of substances other than oil.

Extraction of Oil.—The chief solvents employed in extracting oil are petroleum spirit, carbon bisulphide, and, more recently, carbon tetrachloride. The first is dangerous to use owing to its great inflammability, while the fumes of carbon bisulphide are nauseous and poisonous. Carbon tetrachloride is also dangerous to breathe, but if proper precautions are taken to prevent the escape of the vapour, is the least objectionable of the three.

In extracting the oil the finely divided meal is introduced into a vessel which is tightly closed down, while a current of the solvent is made to percolate through its contents. When this has become charged with the oil it is drawn off, and the material treated with a fresh quantity of solvent, until it is completely exhausted.

Frequently the extraction vessels are placed so as to form a battery, and the solvent passes through them successively, becoming more and more charged with oil on its way; and in some apparatus the extraction is accelerated by the use of steam pipes. Finally, the solvent, with the oil in solution, passes into a vessel heated by steam, in which the solvent is evaporated, leaving a residue of the extracted oil. The solvent expelled from the oil is condensed and returned to the storage tank to be used again.

The use for which the oil is intended largely determines whether it shall be extracted or expressed. In the case of edible oils, such as olive, sesame, maize and earthnut oils, expression is necessary, since it yields a purer product than extraction. It is also advisable to



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SEED HEATING KETTLE AND HYDRAULIC CAKE-MOULDING MACHINE

separate the oil by expression, where it is desired to use the expressed oil-cake as a feeding-stuff for cattle. On the other hand, the extraction process yields a larger proportion of oil, which is also freer from mucilaginous and other foreign bodies.

Refining of Oils.—Whether obtained by expression or by extraction the crude oil requires refining before it can be put upon the market. It invariably contains water, gummy albuminous substances, and resinous and colouring matters, some being in a state of suspension and others dissolved in the oil.

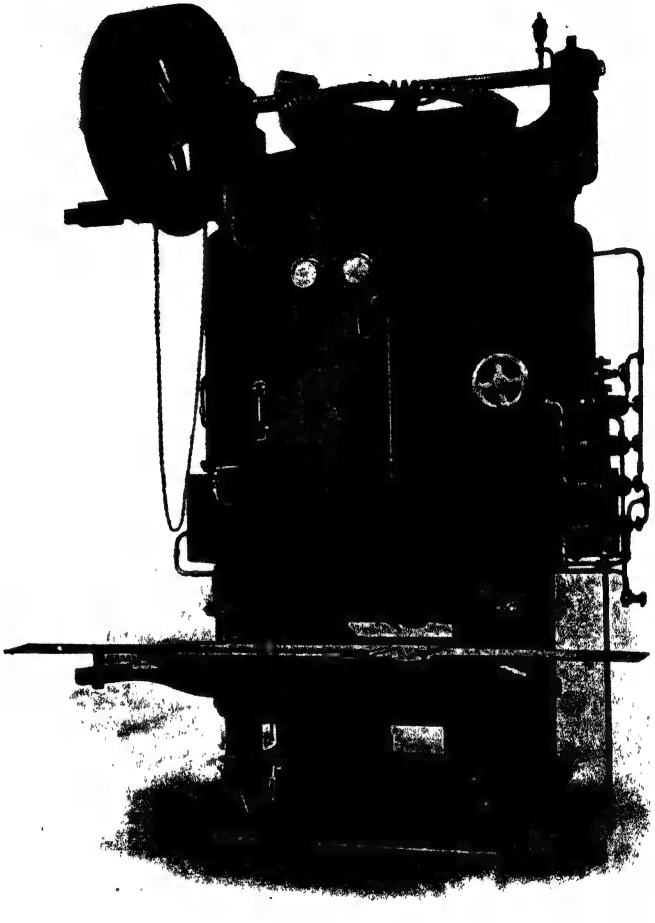
The oil is, therefore, filtered (in some cases after being heated) to separate, as far as possible, all insoluble impurities. Numerous filter-presses are employed for this purpose, some of which are based upon the creation of a partial vacuum, and others upon the use of centrifugal filtration.

Chemical purification is also used in the case of many oils: thus, rape (colza), linseed (and also certain fish oils) are frequently clarified by treatment with dilute sulphuric acid, but the process is objectionable for oils intended for lubricating purposes.

Other oils, notably cotton-seed oil, are refined by treatment with solutions of alkali, which have the effect of coagulating and precipitating mucus and albuminous substances, leaving a clear supernatant layer of oil. These processes have also the advantage of neutralising any free fatty acids present in the oil.

The " foots " or residue separated from oils containing albuminous and resinous matters is generally worked up, in admixture with other materials, into coarse soaps.

The colouring matters of oils and fats are usually due to the presence of organic substances such as chlorophyll, etc. In some cases the oil can be rendered lighter by treatment with animal charcoal and filtration, whilst



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SELF-ACTING CAKE-MOULDING MACHINE
AND SEED HEATING KETTLE

in other cases (beeswax, palm oil) the material is bleached by exposure to the sun, or by treatment with chemicals such as hydrogen peroxide, ozone, or potassium bichromate.

More recently, methods of bleaching by exposing the oil in thin films to the action of rays from an electric arc light or the ultra-violet rays of a mercury vapour lamp have been used.

Special chemical processes are also employed for deodorising oils and fats, and especially cocoanut oil, which in its deodorised form is the basis of most of the so-called " vegetable lards." In one of the most widely employed processes the cocoanut oil is treated with alcohol and animal charcoal to obtain an inodorous and perfectly white product, which is sold under various descriptive names.

Non-Drying Oils

Olive Oil.—Various species of olives are cultivated for the sake of the oil contained in the pulp of the fruit, but the oils differ but slightly from one another in their chemical and physical characteristics, though their qualities and flavour vary.

In addition to *Olea europea*, several varieties of which are grown in Southern Europe, and have been acclimatised in various localities in America and Australia, there are also other oil-producing species (*O. ferruginea* and *O. capensis*), which are utilised in Asia and South Africa.

The degree of ripeness of the olive has a considerable influence on the flavour of the oil, and in order to obtain the finest product it is essential to press the fruit as soon as possible after picking.

The methods of obtaining the oil vary in different districts, and in some cases the stones are ground up and expressed with the fruit. Although the oil from the

fresh kernel closely resembles the pulp oil, the latter is considered to have a better flavour than the oil from the whole fruit and is sold at a higher price.

The crushed pulp or "marc" is usually packed in baskets of esparto grass bound with horsehair bands, which are then introduced into a press, each layer being separated from the next by perforated wooden or metal plates.

The oil obtained by the first expression is known as "virgin oil," and fetches the highest price, while the oils obtained by the second expression and by extraction of the residue with solvents is less pure and is frequently used as a lamp oil or for lubricating purposes.

The crude oil is sprayed to remove mechanical impurities and to precipitate albuminous matters, after which it is run into tanks, and the clear liquid subsequently decanted and filtered.

The best grades of olive oil are of a golden colour and have an odour of the fruit. The second quality, also, known as "table oil," is not so bland in flavour or aroma, while the oil subsequently extracted goes by the name of "ordinary" or "common" oil, and has a greener colour and a sharper and bitter taste.

When exposed to cold, olive oil throws down a white deposit of "stearine," or solid fat. In the so-called "winter oils" this is partially removed, so that the oils will remain liquid, whereas the untreated oils, which only remain clear when kept in a warm place, are known as "summer oils."

The finest grades of oil are derived from Italy and the South of France, and have a considerably higher market value than Spanish, Algerian, or Tunisian oils.

Olive oil is extensively adulterated, the chief substances employed for the purpose being cotton-seed oil, sesame oil and earthnut oil.

Almond Oil.—This oil is expressed from the kernels of the sweet or bitter almond, which contain from 40 to 55 per cent. thereof. There is practically no difference between the characteristics of the oil from either source.

It is a pale yellow liquid with a bland taste, and is very fluid; so much so that it can be chilled far below the freezing point of water without solidifying.

It is principally used for pharmaceutical purposes, and owing to its high price is liable to be adulterated with cheaper oils, and especially with the closely similar oils derived from the kernels of the peach, apricot and plum.

Earthnut or Arachis Oil.—The seeds of the earthnut (or monkey nut), *Arachis hypogea*, yield, on expression, from 30 to 50 per cent. of oil, and the plant is extensively grown for this purpose in Virginia, South America, Africa and India.

The nuts are largely exported, and the oil expressed in Europe, the chief centre of the industry being Marseilles, where an immense quantity of African nuts are treated. The nuts, after being shelled and cleaned by machinery, are freed from the husks by means of the blast of a fan, and are then packed in cloths for the press.

The cold-pressed oil is pale yellow, and is widely employed, under the name of "salad oil," as a cheap substitute for olive oil. The oil subsequently obtained by hot-pressing is of poorer quality, and is mainly used for lubricating purposes and in the manufacture of Castile soap.

Both grades have the characteristic odour of the nuts. When exposed to cold, earthnut oil readily solidifies into a dense white mass.

The residue obtained in the expression of the oil is a valuable seed-cake, which is used for feeding cattle.

Tea-seed Oil.—This oil, expressed in China and Japan

OLIVE TREES

from the seeds of *Camellia sasanqua* or *Camellia oleifera*, is a light yellow liquid used locally in the manufacture of soap, as an illuminant, and for cooking.

Castor Oil.—The seeds of the castor oil plant, *Ricinus communis*, yield about 50 per cent. of oil. The plant is extensively cultivated in every continent, though the bulk of the world's supply is derived from India, which produces annually some 70,000 tons of seeds, and exports upwards of two million gallons of oil.

The product obtained by cold expression of the seeds is preferred for medicinal purposes. The fresh seeds, after being freed from dirt and foreign matter, are crushed between rollers and then wrapped in cloths and lightly compressed into the form of bricks. These are pressed between the perforated plates of a hydraulic press, and the oil collected in vessels placed beneath.

The crude oil thus obtained is purified by the addition of water, which is subsequently evaporated by boiling. In this process the albuminous matters coagulate and the mucilage subsides, so that a pure oil may then easily be obtained by filtration.

Purified castor oil is of a pale straw colour, and remains liquid when cooled far below the freezing point of water. It differs from most other oils in being very soluble in alcohol.

In addition to its uses in medicine, castor oil is extensively employed in the manufacture of the *Turkey-red oil* required in the dyeing and printing of cotton goods. The alizarine dyestuffs have to be dissolved in a suitable solvent that will also penetrate the fibres of the fabric. Formerly olive oil was used for this purpose, but its place is now taken by the "Turkey-red oil" prepared by treating castor-oil with sulphuric acid under suitable conditions.

Curcas Oil, derived from the seeds of the "physic

tree " (*Jatropha curcas*), has many points of resemblance with castor oil. The plant is cultivated in the Portuguese Colonies, and the oil is expressed in Lisbon. It is used as a lubricant, as a lamp oil and in the manufacture of soap and candles.

Rape Oils.—The term " rape " or " colza " oil is used indiscriminately in this country for the oils obtained from the seeds of a number of plants belonging to the *Cruciferae*, but on the Continent a distinction is drawn between the products derived from different species of *Brassica*. Thus, in Germany, the name colza oil is restricted to the oil expressed from the seeds of *B. campestris*, var. *rapus*, while that derived from the seeds of *Brassica rapa* goes by the name of " Rübsen oil," and the product of *B. campestris*, var. *napus*, is known as " Raps " oil.

The seeds of the three plants are very similar in shape and colour, but, as a rule, colza seeds are larger, and yield a higher proportion of oil.

Rape seed is extensively grown in France, Belgium, Germany, Hungary and Russia ; also in China and India.

In Europe a commercial distinction is made between " summer rape," which is sown in the spring and gathered five months later, and " winter rape," sown in the autumn and gathered the following year. The " winter oils " are usually regarded as the better products.

The oil is separated by the general methods of expression and extraction already described, and the residual seed-cake is valuable as a feeding stuff, or (in the case of extracted matter) for manure.

The crude oil is dark brown in colour, but is refined to a light yellow liquid with a harsh taste. It is used in large quantities as an illuminating oil. Among the substances employed to adulterate it mention may be made of linseed, cotton seed, fish, mineral and resin oils.

The oils from the seeds of *Eruca sativa* and Indian mustard seed (*Brassica juncea*), which are used in India as edible oils and for burning, etc., are closely allied to the rape oils.

Semi-Drying Oils

Cotton-seed Oil.—This oil is a typical representative of the semi-drying class, which dry too slowly to be of use in paints and varnishes, and yet, possessing considerable drying powers, are unsuitable for lubricating machinery. It is used, however, in immense quantities as a cheap salad oil, as a substitute for lard in cooking, and in the manufacture of oleo-margarine, while the poorer qualities are made into soap.

By far the largest proportion of the cotton-seed oil of commerce is produced in the United States, and the machinery for treating the seed so as to obtain the greatest yield of oil in an economical manner has there been brought to a high pitch of perfection.

As the seed is ginned it is removed to the factories, some of which have mills capable of dealing with 200 tons of seed in a day. The seed is first conveyed by means of elevators to the storage at the top of the building, whence it can be distributed by means of screw conveyors.

Before being expressed, it is passed through revolving perforated screens, which retain fragments of stalk, stones, sand, and other impurities, and is next conveyed to the "linters," in which the short lint, that would otherwise absorb some of the oil, is removed. The seed thus cleaned is shelled in "hullers," which consist of an outer cylinder and an inner drum, both of which are set with knives that rapidly revolve, and the husks or hulls are separated from the kernels by the action of an oscillating separator or "shaker."

A WEST INDIAN PALM BEACH

The kernels, technically known as the " meats," are now ready for crushing between iron rollers, after which process they are heated in steam-jacketed kettles, and shaped into cakes in a press termed the " former." These cakes are wrapped in hair cloths and subjected in hydraulic presses to a pressure of 3,000 to 4,000 lbs. to the square inch.

The crude oil is pumped into settling tanks, where the impurities subside as " foots," while the clear supernatant liquid is drawn off above and further purified as described in a previous page.

The residual oil-cake is a valuable product and is used in the United States and exported in large quantities as a food for cattle.

When chilled, cotton seed oil yields a considerable amount of a solid deposit of fat, known commercially as " cotton-seed stearine," and sometimes used as an adulterant of lard. Cotton-seed oil itself is also frequently employed to adulterate olive oil.

Sesame Oil.—This oil, also known as Gingelly oil, is expressed from the small flat seeds of *Sesamum indicum*, the yield being about 50 per cent. The plant has been cultivated in the East since a remote period, and is still produced in large quantities in India, Egypt, China and Siam. It is also grown in South Africa, in the United States and in many tropical countries.

The great centre of the sesame industry in Europe is Marseilles, where the greater proportion of the commercial oil is expressed.

The cold-drawn oil has a mild bland taste and is used as a salad oil and in the manufacture of margarin. The oil obtained by hot expression is employed as a lamp oil, and as a lubricant, for which purpose, however, its drying properties render it unsuitable.

Sesame oil is often used to adulterate olive oil, and is

itself liable to be adulterated with cotton-seed oil and earthnut oil.

It contains a small proportion of a constituent known as *sesamol*, which gives a bright pink colouration with certain reagents. In this way it is possible to detect the presence of very small quantities of sesame oil in other oils and fats. Advantage is taken of this property in Belgian and German food legislation, which prescribe that all margarine shall contain 10 per cent. of sesame oil, so that should butter be adulterated with margarine the fraud may be readily detected by means of the "latent colour" of the oil.

Maize Oil.—The seeds of the maize plant, *Zea mais*, contain from 6 to 8 per cent. of oil, which is extensively used, especially in the United States, for food, soap making, and as a lamp oil.

It has an aroma of the grain, and when freshly expressed it is of a pale straw colour, but gradually becomes yellow on exposure to the air.

Croton Oil.—The seeds of *Croton tiglium*, which is cultivated in Southern Asia and China, yield, on expression an oil, which is employed medicinally. The commercial product is sometimes adulterated with hydrocarbons and with castor oil.

Other semi-drying oils that find a commercial use are :—

Kapok Oil, obtained from the seeds of *Eriodendron anfractuosum*, cultivated in the Dutch East Indies for the silky floss (sold as *kapok*) that envelops the seed capsules. The expressed oil is of a greenish-yellow colour, and has many points of resemblance with cotton-seed oil. It is used in Holland in the manufacture of margarine and as a soap material.

Camelina Oil, also known as German sesame oil, obtained from the seeds of *Camelina sativa.* It is used

in the manufacture of soft soap and, to a less extent, as food, and is also employed to adulterate rape oil.

Madia Oil, which is expressed from the seeds of *Madia sativa,* grown in Chili. The best (cold drawn) oil is employed as a food, while the poorer qualities are used as lamp oils, and in the manufacture of soap.

Soja Bean Oil, derived from the soja bean (*Soja japonica, S. hispida*), grown in India and Southern Asia.

Drying Oils

Linseed Oil.—The flax plant (*Linum usitatissimum*) is widely cultivated both for its fibre, and for the oil yielded by the seeds, though Russia is the only country producing both flax and linseed on a commercial scale. In Europe the plant is grown mainly for fibre, while in other countries, notably in the United States, Argentina, Uruguay and British India, the plant is grown almost exclusively for its seed.

The seeds are known in two varieties, red and white, the oil produced by the latter being regarded as the better in quality.

After being stored for some time, the seeds are screened and crushed, and the oil separated by hot expression. Some of the best grades of oil used in Russia as edible oils, or for light-coloured paints, are pressed in the cold, but hot expression is the general method. The crude oil is purified by filtration from the separated albuminous substances and mucilage.

In the United States an extraction method, with naphtha as the solvent, is in common use, the naphtha being subsequently removed by distillation.

Purified linseed oil varies in colour from light yellow to brown. The commercial product has usually an acrid taste and odour, soon darkens and thickens on

exposure to the air and absorbs oxygen to form a dry elastic film.

This drying property is greatly increased by heating the oil in the presence of certain metallic salts (such as litharge), known as "driers." The "boiled" oil thus obtained is much thicker and darker than raw linseed oil, and dries very rapidly when exposed to the air.

Boiled linseed oil is employed as the basis of oil paints and varnishes, in the manufacture of printer's ink, and (in admixture with powdered cork and other materials) for making linoleum.

Linseed oil is liable to be adulterated with cotton-seed oil and other semi-drying oils, with rosin oils, and with mineral oils.

Nut Oil.—The oil expressed from the kernels of the common walnut tree (*Juglans regia*) yield from 40 to 45 per cent. of oil, which is usually known commercially as *nut oil.* The cold-drawn oil is employed as a food oil, while the hot-pressed oil is used for illuminating purposes, and especially a medium for white oil paints, for which its pale colour renders it particularly suitable.

Poppy Oil.—This is another drying oil that is largely employed by artists. It is obtained from the seeds of the opium poppy (*Papaver somniferum*), which is cultivated in Persia, Asia Minor, Egypt and India. It is also grown in France and in Germany, where two varieties with white and black seeds are recognised. The fresh oil obtained by cold expression is used as a salad oil and in cooking, while the darker qualities resulting from hot expression are burned in lamps or made into soap.

Poppy oil is frequently used to adulterate olive oil in France, and is in turn itself adulterated with sesame oil.

Hemp-seed Oil.—The seeds of the hemp plant (*Cannabis sativa*) yield a greenish-yellow oil, which dries

well, though less rapidly than linseed oil. It is grown in Russia and Germany, in Egypt, in Central Asia, and elsewhere. It is used as a medium for oil paints and varnishes and in the manufacture of soft soap.

It is also a common adulterant of linseed oil.

Tung Oil.—The commercial oil, which has now become generally known in Europe, is expressed and extracted from the nuts of *Aleurites cordata* and probably of allied species of plants, which are cultivated and grow wild in different localities in China and Japan.

It is a pale yellow or dark brown oil with an unpleasant odour, which has stood in the way of its general adoption in the linoleum and varnish industries.

It dries with great rapidity and can be used for varnishes without preliminary " boiling."

When heated and exposed to the action of light, tung oil suddenly undergoes a change in form and becomes a sticky, gelatinous mass. This " polymerised " tung oil is used in commerce to prevent the separation of the pigment from the oil in oil-paints put up in tubes.

Candle-nut Oil derives its name from the nuts of the tree (*Aleurites moluccana*), being used by the natives of the South Sea Islands as candles. The tree is common in those islands, and the oil obtained from its nuts is used for making soft soap and as a varnish.

Safflower Oil.—This oil, also known as saffron oil, is expressed or extracted from the seeds of *Carthamus tinctorius*, which is cultivated in India, Egypt, China, and, more recently, in South Russia. It resembles walnut and poppy oils in its general characteristics.

Sunflower Oil is a good drying oil, which is obtained from the seeds of the sunflower (*Helianthus annuus*), grown extensively in Russia. It is used as a food and for making varnishes, etc.

Niger-seed Oil.—This is a pale yellow oil with good

COPRA DRYING

drying properties. It is expressed from the seeds of *Guizotia oleifera*, an annual plant cultivated to a considerable extent in India, Abyssinia and Egypt.

Vegetable Fats

Palm Oil and Palm-kernel Oil.—Two different fats are obtained from the fruit of the West African oil-palm (*Elaeis guineensis*), viz.: palm oil, a yellow or red-coloured fat separated from the fruit pulp, and palm-kernel oil, a white fat expressed from the kernels of the seeds.

In addition to the West Coast of Africa, the oil palm also flourishes in Zanzibar, in Central Africa, and in the Philippine Islands. It grows to a height of 30 feet or more and produces large "heads," in each of which are several hundred fruits.

In preparing the oil, the fruits are boiled to a pulp with water, and the mass, after cooling, pressed by men treading on it in a trough. The oil rising to the surface is skimmed off and passed through a sieve to remove impurities, after which it is heated and separated from the water.

As thus obtained, palm oil is a fat varying in colour from orange yellow to dirty red, and having a characteristic sweet odour and taste. In its fresh condition the natives use it as food, while large quantities are exported to Europe for the manufacture of soap and candles, and for use as a grease to prevent the oxidation of iron plates before being tinned.

The oil from the kernels, which is also known in commerce as "palm-nut oil," is prepared by cracking the nuts between stones and separating the kernels. These are imported to Europe and expressed in hydraulic presses by the methods already described.

Cocoanut Oil.—The cocoanut palm, which produces

this important fat, flourishes in Madras and other districts of India, in Ceylon, in the West Indies, the Malay Peninsula, South America, East Africa and many other tropical localities.

After removal of the outer fibrous covering, which yields the coir of commerce, the ripe nuts are broken, and the kernels either expressed locally, or cut into pieces, dried and exported under the name of coprah.

Cocoanut oil is a soft white fat, which melts at a low temperature and has a characteristic odour and taste. It readily turns rancid, and various commercial processes of checking this tendency and of removing the odour have been devised. These deodorised products are sold under various fancy names as vegetable substitutes for butter and lard.

Cocoanut oil is a common adulterant of cow's butter, which it somewhat resembles in chemical composition.

Cacao Butter (Cocoa Butter) is derived from the seeds of the cacao tree (*Theobroma cacao*), and is obtained in large quantities in the manufacture of chocolate. It is a hard yellowish white fat having an aroma of cacao. It is extensively used as the fat for chocolate creams. It is frequently adulterated, especially with cocoanut oil, stearic acid, tallow and paraffin wax.

Japan Wax is derived from the berries of *Rhus succedanea* and allied species of *Rhus*, which are cultivated in Japan. Although it resembles wax in appearance, it is chemically as much a fat as cocoanut oil. It is a hard, brittle, yellowish-brown substance, which is used as a substitute for beeswax in the manufacture of furniture polishes, etc.

Among other vegetable fats mention may also be made of the following :—

Macassar Oil, expressed from the seeds of the Indian tree *Schleichera trijuga*, and long used as a hair restorative,

Kokam Butter, contained in the seeds of the plant *Garcinia indica,* which is used in India as a food and for making soap.

Carapa Fat, which is a thick white fat obtained from the seeds of various species of *Carapa* growing in India, Brazil and West Africa. It is used in the manufacture of soap.

Shea Butter, from the seeds of *Butyrospermum Parkic,* which grows in northern tropical Africa. It also is used in the manufacture of soap and candles.

Phulwara Butter, produced by *Bassia butyracea,* a tree known as the Indian " butter tree."

Mahua Butter, the product of other species of *Bassia,* growing in India.

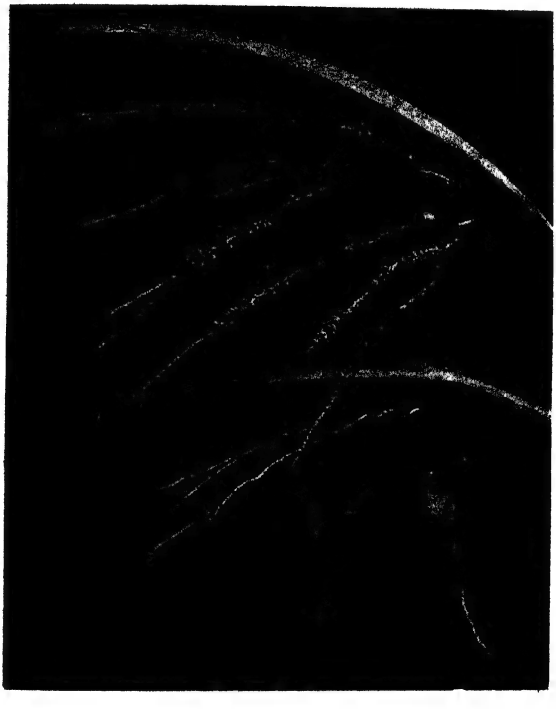
An important use of these and similar vegetable fats is the preparation of cheap substitutes for cacao butter for the " cream " of chocolate creams.

II. ANIMAL FATS AND OILS

Solid Fats

Lard.—In the preparation of lard from the fatty tissues of the pig the material is finely divided and " rendered " in a digester into which steam, usually under pressure, is introduced. In some of the large American factories a series of these digesters, each having a capacity of 10,000 to 15,000 gallons, is employed, the melted fat being drawn off through a perforated false bottom.

In the American trade lard is classified into various grades, including (1) *Neutral lard,* the fat from the fresh leaf of the pig rendered at a low temperature ; (2) *leaf lard,* from the residue of (1) rendered under pressure ; (3) *choice lard,* consisting of leaf and back fat ; (4) *prime steam lard,* the fat from the head, heart and intestines ;



COCO-NUTS

and (5) *guts*, derived from all parts of the animal, except the lungs and heart.

There is a considerable difference in the chemical composition of American and European lards, the former being of a more fluid character. The fat from different parts of the same pig also varies greatly in its composition and characteristics.

Lard is often adulterated with beef fat and then rendered sufficiently soft again by an addition of a vegetable oil such as cotton-seed or maize oil.

Tallow.—The name " tallow " is given to the fat from many kinds of animals, but particularly the ox and sheep. The various grades known in commerce are described under names indicative of their origin, such as " River Plate tallow," " Russian tallow," etc. As a rule, the Russian products are more solid and melt at a higher temperature than the other grades.

Tallow may be adulterated with cheaper fats, such as cotton-oil stearine, or with non-fatty substances, such as paraffin wax.

Beef Fat.—The fat of the ox varies in characteristics with the part of the animal whence it was taken, but is much more solid than lard. It forms the chief basis of oleo-margarine, which is made up into margarine and other butter substitutes.

Margarine.—The first attempts upon a manufacturing scale to prepare a butter substitute from animal body fats, dates back to the siege of Paris, when Mège Mouriés devised a process of preparing it, chiefly from horse fat.

In the modern processes the fat from beef or mutton suet is pressed so as to obtain a compact fat, termed " beef stearin," which is largely employed in making artificial lard, and a semi-solid oily fat. The latter is churned up with fresh or sour milk and sometimes with " renovated " butter, and coloured to imitate butter.

When the beef fat is too stiff it must be thinned down with a vegetable oil.

Various patents have been taken out for processes to imitate the characteristics of butter still more closely.

Deer Fat.—The fat rendered from the tissue of various species of deer is white and hard, and is similar to tallow in its composition and characteristics, and is used for similar purposes.

BUTTERS

Cow's Butter.—The only milk-fat of commercial importance in Europe is that prepared from the milk of the cow.

Butter usually contains from about 11 to 16 per cent. of water; 83 to 87 per cent. of butter fat; and from 1 to 3½ per cent. of solid substances other than fat (including salt, casein and milk sugar). In Irish butters the percentage of water is often considerably higher, while in preparations that have been "blended" with milk it may be 25 per cent. and over.

The characteristics of the fat vary with the breed of cows and with the conditions under which they are kept. Thus, Dutch butter frequently has an abnormal composition, which suggests adulteration with body fats or vegetable fats. This has been found to be principally due to leaving the cows too long in the fields, and after stalling the animals the butter soon becomes normal.

The nature of the food given to the animals may also have an influence upon the composition of the butter fat. For instance, cows that have been fed upon cotton-seed cake produce butter-fat that gives the reactions for cotton-seed oil.

Butter fat differs from body fats in yielding a large proportion of volatile fatty acids, and the tests of the purity of a sample depend largely upon this characteristic.

The chief adulterants of butter are cocoanut oil and palm oil (which also yield volatile fatty acids), and margarine, which is prepared from animal fats and vegetable oils.

Renovated or "process" butter is the commercial name of a product consisting of stale butter that has been melted down and the fat re-churned with butter-milk. The fraudulent sale of this product as fresh butter is not easily detected, and reliance has mainly to be placed upon the differences in their microscopical appearance

Animal Oils

The chief animal oils of commercial importance are the following :—

Neat's-foot Oil, which is a pale yellow very fluid oil, derived from the "feet" (hoofs and hocks) of various animals (oxen, horses, sheep). It is used as a lubricant for clocks, watches and other delicate machinery.

Lard Oil, which consists of the more liquid portion of lard, is obtained by expressing lard in bags of close texture, in a hydraulic press. The residual more solid fraction is known as "lard stearine," and is used in the manufacture of the best grades of soap.

Tallow Oil, which is obtained from ox-tallow and mutton-tallow in the same way as lard oil, the solid residue in this case being known as "tallow stearine."

Chrysalis Oil.—Oil is now extracted in large quantities from the chrysalis waste in the silk-producing districts of Japan. It is a yellowish-red liquid with an unpleasant odour, and is used in the manufacture of soap.

Fish Oils and Marine Animal Oils

The fat of fishes and of whales and other marine animals differs greatly in physical characteristics from the fat of land animals, and consists of oils which have

many points of chemical resemblance with linseed oil, although lacking the latter's drying properties.

Cod-liver Oil.—This oil, as its name indicates, is separated from the liver of the cod-fish (*Gadus morrhua*). The fresh livers are first stored in open barrels to allow a certain proportion of the oil to exude spontaneously, after which they are heated in pans surrounded by a jacket of steam. Lastly, the residual tissue is boiled with water and an inferior grade of oil of a brown colour separated.

In some factories processes are used in which the material is kept out of contact with the air, so as to prevent oxidation and the development of unpleasant flavours.

In addition to the medicinal cod-liver oil, a dark brown product derived from old livers is sold under the name of "cod oil."

Cod-liver oil contains various nitrogenous compounds, and it is to these that its therapeutic action is probably due.

Menhaden Oil is obtained from the menhaden (*Alosa menhaden*), a North American fish. The fish is first steamed and crushed and then gently pressed to obtain the best oil. The residue is next boiled or steamed and subjected to heavier pressure, which yields an oil of inferior quality to the first runnings, while the final residue is worked up into fish manure.

Menhaden oil is chiefly employed in the currying of leather and in the manufacture of cheap soaps. It is also occasionally used as an adulterant of linseed oil.

Sardine Oil is an important commercial product, which is derived from various species of *Clupea*. The Japanese oil, considerable quantities of which are expressed and refined in Yokohama, differs considerably from the European sardine oils.

All are used in the manufacture of soap and as lubricants. The solid fat which deposits from the oil on standing is sold as "fish wax" or "fish stearine."

Among other commercial oils of this class mention may also be made of the following :—

Shark Oil, expressed from the livers of different species of shark.

Whale Oil, derived from the blubber of different species of whale, and used in large quantities, especially in the United States, as a lubricant and for soap-making.

Porpoise Oil, from the jaw or from the whole body of the porpoise, the two oils differing considerably in characteristics.

Dolphin Oil, from the blubber of the dolphin.

Many of these oils are mixed together before being sold.

Hardened Oils

The principal development in the oil industry during the last four or five years has been the production of solid fats from oils. Enormous quantities of hardened oils are now manufactured both for food and industrial purposes in Europe and America.

In brief, the process consists in making hydrogen combine with the unsaturated compounds in oils so as to form a saturated solid fat.

Various types of apparatus are used for the purpose, but the principle of each is essentially the same. The oil is mixed with a finely divided metal or metallic compound, such as nickel or platinum, which is distributed over a porous medium. The mixture is heated in a tube or vessel through which is passed a current of hydrogen. The nickel or other metallic substance acts as a conveyor between the hydrogen and the fat. It is what is known as a "catalytic agent," and in its absence the hydrogen would not combine with the oil.

In this way it is possible to transform an evil-smelling fish oil into a white odourless fat, with a consistency ranging from that of soft lard to that of a hard tallow, according to the duration of the hydrogenation.

Some idea of the extent of the new industry may be gained from the fact that in 1912 the world's supply of whale oil was estimated at 1,200,000 barrels (about 42,000 tons) more than half of which was derived from Norway. Nearly the whole of this whale oil is now hydrogenated into solid fat, which is used in the manufacture of soap.

Large factories for hardening oils have been established in this country, in France (notably at Marseilles), in Germany, and in the United States.

The most important German works are the Bremen-Besigheimer Oelfabriken, where only the best oils are hydrogenated to produce edible fats which are sold under the name of *Brebesol*, and the Germania works at Emmerich, where whale and fish oils are hardened into the technical products, *candelite* and *talgol*.

According to the Customs returns for 1913, the amounts of crude oils imported into Bremen in that year were estimated at 212,000 tons, with a value of upwards of £2,500,000.

Since the war the output of hardened oils in Germany must have shrunk to very small limits owing to the want of oils. The hydrogen plant in these works is reported to have been utilised for the production of gas for air-ships.

In the United States " compound lard " is now made mainly from hydrogenated cotton-seed oil. The total capacity of the plant for hardening oil in Europe was estimated for 1914 at 1,375,000 barrels of 400 lbs., while the United States' output for 1913 was approximately 500,000 barrels.

Hardened oils usually contain a trace of nickel or other metal which has been dissolved in the process. Experiments have shown that about 99·8 per cent. of this nickel is rapidly eliminated from the system when the fats are eaten and no injurious effects from its continued use have been recorded. Care is taken that only the finest oils, such as refined cotton-seed, earthnut and maize oils, are used in the preparation of the hydrogenated products intended for food.

III. WAXES

As has been stated on a preceding page, the waxes differ from fats in containing, in place of glycerin, some other alcohol in combination with fatty acids.

The most important members of this group are beeswax, carnauba wax, wool fat, spermaceti, and sperm oil, which notwithstanding its oily nature, is chemically just as much a wax as beeswax.

Beeswax.—This familiar product is prepared by melting the wax, after separation of the honey, and casting it into blocks, which are sold as " virgin wax."

For certain purposes bleaching is required, and this is effected either by exposing the wax, cut into thin strips, to the action of the sun, or by means of chemical agents, such as potassium bichromate and sulphuric acid.

Considering the diversity of its origin beeswax shows remarkable constancy in its chemical composition, though Indian and Chinese waxes differ in many respects from the European products.

Beeswax is frequently adulterated, and especially with stearic acid, carnauba wax, and paraffin wax.

Carnauba Wax.—This consists of a deposit which exudes from the leaves of the wax palm (*Copernicia cerifera*), a tree growing in Brazil and other parts of South America.

It is a dirty greenish-grey wax-like solid, which is used in the manufacture of wax candles and floor polishes, and is also a common adulterant of beeswax.

Wool Fat.—This consists of the fat deposited in perspiration on the fleece of sheep. It is extracted either by washing the fleece with soap, or, as is more usual on the Continent, by means of a solvent, which is subsequently evaporated. The "wool grease" thus separated is generally purified by distillation with superheated steam, and when formed into an emulsion with water is sold under the name of "lanoline."

Wool fat has a very complicated chemical composition, but is much more akin to the waxes than the true fats, although it contains certain glycerides.

Sperm Oil.—This liquid wax is obtained from the blubber or from the contents of the cranial cavity of the Cachalot whale, the latter product differing in many respects from the former.

It is a pale yellow oil, which is nearly odourless when expressed from fresh material. It is a valuable lubricant, since it shows no tendency to become viscid on exposure to the air. It is sometimes adulterated with low-grade fish liver oils.

Arctic Sperm Oil, also sold as *Bottlenose oil*, is obtained from the bottlenose whale (*Hyperŏodon rostratus*), and resembles ordinary sperm oil in its chemical and physical characteristics. It is used as a lubricant.

Spermaceti.—This is a white wax, which is obtained from the "head matter" of the Cachalot whale, and is also deposited when sperm oil is allowed to stand.

Analogous deposits are obtained from the blubber oils of various cetacea, from which they are separated by gentle pressure in hair cloths.

Spermaceti is liable to be adulterated with hard tallows, animal waxes, and paraffin wax.

PART II

ESSENTIAL OILS

Nature of Essential Oils.—The term "essential oil' is used as a convenient group-name for a class of volatile substances occurring in various parts of plants. It is a survival from the days of alchemy, when every substance was supposed to contain some essence or active volatile principle to which it owed its characteristic properties. Now the name is restricted to scent-bearing oily products of vegetable origin, most of which may be distilled without decomposition at the ordinary atmospheric pressure.

It is to these oils that flowers owe their scent, and spices their fragrance, and an aromatic plant, such as cinnamon, for instance, may be completely freed from its distinctive odour and flavour by extracting its essential oil. The aroma will then be concentrated in the separated oil, whilst the residual plant-structure will be devoid of the original taste or smell.

Distribution in the Plant.—Essential oils are secreted in different parts of the plant. In scented flowers, such as the rose, they are chiefly concentrated in the petals of the flower; whereas in spice-producing plants the chief deposit may occur in the leaves and bark, as in the case of cinnamon, or in the fruit (nutmeg); while in some cases (*e.g.*, in certain kinds of pine tree) the essential oil may be distributed in varying proportions throughout all parts of the plant.

The part played by essential oils in the life-history of the plant is obscure, though doubtless in the case of unfertilised blossoms the scent attracts the insects carrying the fertilising pollen.

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A DISTILLATION APPARATUS

Some light is also thrown upon this point by recent experiments made in France to determine the relative distribution of oil in different parts of perennial plants at various stages of their growth. In the case of wormwood (*Artemisia absinthia*) it was found that at an early period the roots were free from oil, and that the leaves contained more oil than the stem. The proportion of oil in the whole plant then steadily increased up to the flowering period, when the leaves contained twice their former proportion. In the later stages of flowering the proportion of oil in the root increased, while that in the other parts of the plant diminished.

Similarly in the case of vervain (*Verbena triphylla*) the process of flowering was accompanied by destruction of the scent-bearing constituents, probably by an oxidation process, in order to supply the energy required for the work of fertilisation.

The practical application of the results of these experiments is that in order to obtain the best yield of essential oil from the leaves of such perennial plants it is advantageous to retard the flowering period as long as possible, and in any case, to distil the oil before the blossoming time.

Preparation.—The earliest method of separating the oil from the plant by distillation was to mix the finely divided material with water in a copper still, and to heat the mixture over a fire. The steam passing over carried with it the fine particles of oil, and both were condensed in a suitable receiver.

As there is considerable risk of spoiling the oil by over-heating in this process, it is now more usual to place the material in wire cages suspended within the still, or upon a perforated false bottom, so as to prevent all chance of its coming in contact with the heated bottom of the still. A modification of this kind is still widely

employed in the distillation of essential oils from flowers in different parts of England, and the admitted excellence of English oils shows that the process, notwithstanding its disadvantages, leaves little to be desired as regards the quality of its products.

It is now being gradually superseded, however, by processes in which the still is not heated directly, but receives a current of steam generated in another vessel. The still is heated either by means of a steam jacket or by means of a closed steam coil. In this way the distillation may be effected at any desired temperature and pressure, and it is thus possible in the case of very delicate perfumes to separate the oils with less injury to their fragrance, by means of distillation at less than atmospheric pressure.

The distillate, whichever process is used, consists of a mixture of water and the essential oil. In most cases the latter is lighter than the water, and therefore rises to the surface in an oily layer, which is subsequently skimmed off and filtered.

Another method of separating oils, which is only applicable when the substance contains a large proportion of oil, is by means of expression either by hand or by machinery. This method is chiefly used in obtaining the oil from the peel of lemons, limes, oranges, and similar soft material rich in essential oil.

The fruit is cut into halves or quarters, and the adhering acid pulp removed. The portions of rind are then either squeezed against a sponge held in the right hand of the workman, or in the cases of halves are pressed against it and rotated. In this way the small cells in which the essential oil is secreted are broken, and as the oil exudes it is absorbed by the sponge. When the latter becomes saturated the oil is squeezed out into a receptacle

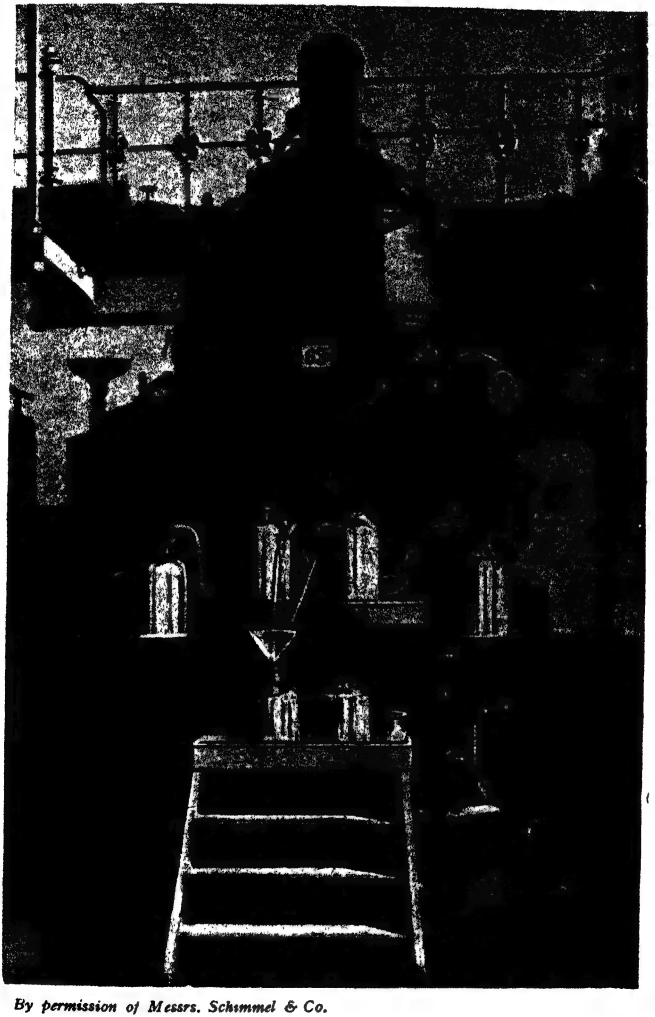
In the West Indies, where lime oil is made on a large scale, the portions of rind are drawn across upright brass needles fixed in the bottom of a bowl, or the whole fruit is gently rolled over the points. The oil cells are thus pricked by the needles, and the oil flows out and accumulates at the bottom of the bowl.

The "expression" and "pricking" processes do not remove the whole of the oil from the rind, and the rest may be obtained by distillation with steam. The distilled products, however, are of inferior quality and fetch lower prices in the market.

In addition to these, a third method is also employed, especially in cases where the delicacy of a perfume is likely to be injured by long-continued contact with steam. The flowers or other parts of the plant are macerated with a solvent, such as alcohol or petroleum spirit, that will take up the essential oil. The extract is separated from the residual plant-substance, and the solvent separated from the essential oil by evaporation at a low temperature.

The French process of "*enfleurage*" embodies a similar principle. The freshly-picked flowers are heated and stirred for several hours with a pure neutral fat, such as olive oil or lard, which extracts all trace of perfume from them. The fat is then strained off, and the essential oil separated from it by extraction with alcohol, which, in turn, must be expelled by evaporation at as low a temperature as possible.

The delicacy of the scent depends largely upon the length of time during which the heated oil was in contact with the flowers, and in the preparation of some of the most highly-prized perfumes the extraction of the oil from the flowers is, therefore, effected by means of cold neutral lard. The process, however, is both tedious and costly.



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A MODERN STILL

A method of extraction occasionally employed in the preparation of the coarser kinds of perfumes consists in conducting a current of hot moist air through a vessel containing the flowers. The air, bearing with it the vaporised essential oil, is next passed through a suitable solvent, such as carbon bisulphide, which will retain the oil, and allow the air thus deodorised to escape.

Properties.—As a rule the essential oils, obtained by one of the methods described, will be mobile liquids, with a strong refractive action upon light. Some oils, however, such as rose oil, are semi-solid at the ordinary temperature, and others, again, are solid substances which melt when gently heated.

They may be colourless, or range in colour from pale yellow to greenish brown or dark brown. Usually they are inflammable and burn, like turpentine, with a smoky flame. The majority of essential oils are lighter than water, but some, of which oil of cloves and oil of cassia may be cited as examples, are heavier than water.

When exposed to the air they frequently undergo changes, probably caused by atmospheric oxidation, and deteriorate in quality. Lemon oil, for instance, gradually loses its fresh aroma and acquires an odour recalling that of turpentine.

To prevent such alterations it is necessary to keep essential oils in tightly-sealed vessels and in the dark.

Volatile oils are nearly insoluble in water, but dissolve readily in certain solvents such as alcohol and petroleum spirit.

Soluble Essences.—The commercial products sold under this name usually consist of an essential oil dissolved in alcohol or other solvent, or in a mixture of alcohol and glycerin. An aqueous liquid, such as lemonade, when mixed with such a preparation is able

to dissolve and retain in solution much more of the essential oil than would otherwise be possible.

Composition.—Essential oils show as wide variations in their composition as in their general properties. Exceptionally, as in the case of winter-green oil, they are composed of a single chemical compound in an approximately pure condition, but as a rule they may be regarded as a blend of several constituents, which may be separated from one another by fractional distillation or other means.

Frequently the fragrant odour of the oil is due to one or two only of these constituents, while the others are inactive in this respect. In the case of lemon oil, for instance, the principal odoriferous compound is a substance termed citral, which usually constitutes a little over 5 per cent. of the oil. The remaining 95 per cent., consisting, in the main, of hydrocarbons, called *terpenes*, apparently does not contribute to the fragrance of the oil.

Terpeneless Oils.—In the commercial preparations known as *terpeneless oils*, the inert inodorous terpenes have been separated by distillation from the small amount of the active constituents, and the whole fragrance of the original oil is thus concentrated into a small bulk, and intensified by the absence of the other compounds.

Terpeneless oils of lemon, orange and ginger are often used with advantage by mineral water manufacturers, the greater initial cost being more than compensated by the purity of aroma and the greater flavouring power.

Influence of Climatic Conditions.—As in the case of most natural products the composition of essential oils varies considerably under the influence of external conditions such as soil and climate. Thus, the essential

oils derived from certain French plants differ to a marked extent in composition from those obtained from English plants of the same species, and the English varieties when grown in French soil produce an oil which gradually tends to approximate to the type of the French product.

Apart from this, the particular variety of plant, and the stage of growth have also been found to have an influence upon the chemical composition, as well as upon the yield of the oil.

Classification.—Essential oils are usually classified in accordance with the botanical relationships of the plants from which they are derived, but here they may be more conveniently grouped according to the commercial uses to which they are mainly put.

As they are employed as perfumes, flavouring agents, drugs and solvents, it will be readily understood that the number of these products upon the market is very large. In the following pages, therefore, it will only be possible to deal with the most important and typical oils in each class.

It need hardly be mentioned that as in all classifications of natural objects there must inevitably be overlapping, and that some of the oils might be placed in two or even in all of the groups.

Volatile Oils Used in Perfumery

To this group belong all those delicate flower-scents, chiefly obtained by the methods of *enfleurage* already described; odoriferous oils, such as *bergamot*, derived from the peel of fruits; oils such as *bay oil*, from the leaves; or, like *orris oil*, from the roots or rhizomes; or from other parts of the plant.

The amount of oil secreted by the plants varies very greatly. Thus, from rose leaves only about 0·02 per

cent. may be separated, and not more than a tenth of that quantity from mignonette flowers, whereas from cassia bark more than 1 per cent. of oil may be distilled, from lavender flowers about 1½ per cent., and from santal wood as much as 5 or even 6 per cent.

Rose Oil.—The most prized of all the scents won from flowers is the essential oil of the rose, which is also known commercially as "*otto*" (a corruption of "*attar*") of roses. For centuries it has been prepared in Persia and other Eastern countries by a primitive method of distillation, and has been used there as the chief scent in perfumery.

At the present day Bulgaria, "the rose garden of the world," is the chief source of the commercial "otto" of rose; for although considerable quantities are distilled in Persia, India and elsewhere, it is rarely that these kinds find their way to Europe.

Otto of roses is also prepared in Algiers to a limited extent, and by Messrs. Schimmel & Co. from the roses grown in their plantations near Leipzig.

The flower cultivated for the preparation of rose-oil in the Balkans is the red rose, *Rosa damascena*, but a white rose, *R. alba*, is often mixed with it, so as to obtain a product which will melt at a higher temperature, and thus permit of adulteration with geranium oil with less risk of detection by the local test of taking the melting point of the oil.

In the South of France the petals of the "cabbage rose" (*Rosa centifolia*) are distilled to obtain the commercial "rose water," which consists of water or very dilute spirit containing a trace of rose oil in solution. Nearly the whole of the oil prepared in this district, however, with the exception of a small quantity used locally, is utilised in this way or in the manufacture of rose pomade.

The delicacy of the perfume of the oil depends not only upon the variety of the rose, but also upon its being grown in a particular soil and climate. This explains why attempts to produce a good oil from Bulgarian roses grown under different conditions have only been moderately successful, in spite of greatly improved methods of distillation.

The method of obtaining the oil in Bulgaria is still of a very primitive nature. The flowers are picked early in the morning, and, except on dull days, the work ceases before noon, so that the petals shall not be injured by the heat of the sun. They are immediately taken to the distilleries as the quality of the oil suffers from delay in distillation. During the season of 1908, for instance, the stills were unable to keep pace with the large consignments of rose leaves collected, and huge quantities of the leaves were allowed to stand in heaps, and were consequently spoiled.

To remedy this drawback attempts are now being made to introduce modern distillation apparatus, or to extract the oil by means of ether, or some other solvent.

The simple stills that have long been employed for the purpose are copper vessels about 3 feet in height, taking a charge of about 20 gallons of a mixture of the leaves and water. These are heated over small brick furnaces, and the steam and vaporised rose oil pass from the still through a straight or spiral tube contained in a tub, through which runs a constant current of cold water.

The successive distillates of rose water thus obtained are united and redistilled, until the oil is present in sufficient quantity to be drawn off as a layer from the surface of the water. About 3,000 lbs. of rose leaves are required to obtain 1 lb. of rose oil.

" Otto " of roses is almost systematically adulterated, especially with the cheaper geranium oil, and it is sometimes by no means an easy task to detect the fraud, owing to natural variations in the chemical composition of the genuine product. In doubtful cases, reliance has often to be placed upon the judgment of the trained specialist, who bases his conclusions as to the purity of a sample upon its odour.

Geranium Oil.—This finely-scented oil is prepared from the green leaves of several species of *Pelargonium*, which are cultivated for the purpose in Spain, Algiers, Italy and the South of France.

As a rule the whole of the plant is distilled, and occasionally rose petals are also introduced into the still to intensify the natural rose-like odour of the product. The resulting distillate from such mixtures has a fine odour, and is sold as " rose-geranium " oil.

Geranium oil is widely employed in perfumery either by itself or when blended with other oils. It is sometimes used to adulterate " otto " of roses, although the so-called geranium oil systematically used for that purpose in Bulgaria is the " *Indian geranium oil* " (also known as " *Turkish geranium oil* " and " *Palmarosa oil* "). This is distilled in India from a species of grass, *Andropogon Schoenanthus*, and is much inferior in odour and consequently cheaper than true geranium oil, which therefore frequently contains it as an adulterant. By itself it is used as the basis of cheap coarse scents.

Lavender Oil.—Various species of lavender are used in the preparation of the commercial essential oil, but by far the largest proportion is obtained from the flowers of *Lavandula vera*, which grows abundantly in sunny stony localities in the countries bordering on the Mediterranean, and is also cultivated in various parts of France, in Italy, and even as far north as Norway.

The lavender that was used in classical times by the Romans as a perfume for the bath was probably *Lavendula Stoechas*, a shrub producing dark purple blossoms with an odour more akin to rosemary than to ordinary lavender. The flowers of this species were used medicinally in England until about the middle of the eighteenth century.

Decoctions of the flowers of the ordinary lavender were also used as drugs in Wales as far back as the thirteenth century, and the oil has always been official in the London and British Pharmacopœias.

According to Culpepper's old herbal (1782), " Lavender is of special good use for all the griefs and pains of the head and brain that proceed from a cold cause . . . but the chymical oil drawn from Lavender is of so fierce and piercing a quality that it is cautiously to be used either for inward or outward griefs." Now, it is chiefly as a flavouring agent that it finds its use in medicine.

In the South of Europe a large export trade is still carried on in the dry lavender blossoms, but in this country the plant is now almost exclusively cultivated for its oil.

The principal English lavender plantations are at Carshalton in Surrey, at Hitchin in Hertfordshire, and near Canterbury. The cultivation of the plant has for many years been discontinued at Mitcham, although some of the oil is still distilled in the neighbourhood, and the finest products continue to be described as " Mitcham lavender oil."

The flowers are gathered early in August, and are distilled as soon as possible afterwards. The early method of distillation in wide-bottomed copper stills over a direct source of heat, as described above, is still in common use, and although distillation in a current

of steam would give many advantages over this method it could hardly produce a finer product.

In making the most refined lavender oil the blossoms are carefully separated by hand from the stalks, and this necessarily adds several shillings per ounce to the cost. The oil in the stalks has a much coarser odour, and is less volatile than the flower oil. Hence the better grades of lavender oil are those separated during the earlier stages of the distillation. Where the entire plant is distilled, the product is inferior in odour and fetches a lower price.

The proportion of oil yielded by the flower varies greatly with the kind of season, and cold dull weather during the early blossoming period greatly reduces its amount. As a rule an acre of lavender should produce about 20 lbs. of oil, though after a specially good season the amount may reach 30 lbs. On an average the flowers will contain about 1½ per cent. of essential oil.

Lavender, which grows wild or is cultivated in the South of France, is distilled near Montpellier and in other places, but the French oil has never been able to compete in the market with the English product, which frequently fetches ten times the price.

The cause of this difference appears to be due to the influence of soil and climate upon the composition of the essential oil in the plant. All attempts to acclimatize the English lavender upon French soil have been unsuccessful in this respect, for the plants gradually acquired the characteristics of the French lavender, and produced a similar oil. On the other hand, French lavender transplanted to English soil soon adapts itself to the new conditions, and yields an oil with the same composition and delicacy of odour as the English plant.

Lavender oil is only soluble in traces in water, and the so-called "lavender water" now consists in reality

of a solution of the oil in dilute rectified spirit of wine, the scent being sometimes modified by the addition of rose oil or oil of bergamot.

In addition to the fraudulent substitution of French oil for English oil, which may sometimes be detected by a determination of the chemical composition, lavender oil is also frequently adulterated with turpentine and with spike oil. Chemical and physical tests are used in the detection of these adulterants.

Spike Oil.—An essential oil, which is sold under the name of " spike oil " or " spike lavender-oil," is distilled from the flowers of the spike lavender, *Lavendula spica*, a plant growing in the same districts as the true lavender. Its odour is coarser than that of lavender, and somewhat recalls the odour of rosemary.

Spike oil is a common ingredient of the cheaper kinds of scent, and is also frequently used to adulterate lavender oil, while in turn it is itself adulterated with turpentine oil.

Rosemary Oil.—The flowers of the well-known shrub, rosemary (*Rosmarinus officinalis*), yield an essential oil, which is extensively used in conjunction with other oils in the manufacture of various scents, including *Eau de Cologne*, and is also employed to a limited extent for scenting ointments and other pharmaceutical preparations.

The oil is separated from the freshly-gathered flowers in the same way as lavender oil, similar care being taken to exclude the stalks in the preparation of the finest grades.

Only a very small proportion of the commercial oil is distilled in England, the bulk being derived from the South of France, and from the islands off the Dalmatian coast. The odour of the Dalmatian product, which through being imported by way of Trieste is known in

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A ROSE HARVEST

commerce as *Italian rosemary oil*, is greatly inferior to that of the French oil. This is possibly due in part to climatic difference, but is also probably largely the result of the use of very primitive stills, and want of care in the distillation.

The odour of rosemary oil is strong and penetrating, and resembles that of the plant blended with camphor. By suitable treatment a solid constituent termed *rosemary camphor* may be separated from the oil.

Rosemary oil is commonly adulterated with turpentine and petroleum oils, and the finest sorts are sometimes cheapened by an addition of spike oil. As the production of the Dalmatian oil is under municipal control the chief adulteration of this kind of oil probably takes place after it has left the islands.

Neroli Oil.—The flowers of the sweet and bitter orange yield, on distillation with water, essential oils which differ both in odour and in composition from the oil contained in the peel of the fruit.

In commerce a distinction is drawn between the oil obtained from the flowers of the bitter orange tree (*Oil of Neroli, Bigarade*), and that derived from sweet orange flowers (*Oil of Neroli, Portugal*), the former being the more fragrant and fetching about twice as much in the market. Hence it is not an uncommon practice for the two oils to be mixed, and sold as bigarade neroli oil.

Most of the oil in the market is prepared in the South of France. The flowers are collected, usually in the month of May, and the petals mixed with water and distilled in a still heated by means of a steam coil. The essential oil rising to the surface of the distillate is drawn off, while the aqueous portion is sold as " orange-flower water."

Neroli oil is in considerable demand for the manufacture of perfumes, and is worth about 5s. to 10s. per

oz., according to its origin. Adulteration with ordinary oil of orange is very common, and is not easily detected. *Oil of Petits Grains* is also frequently added as an adulterant.

Oil of Petits Grains.—This oil was originally derived from the seeds of the sweet and bitter orange tree, but is now almost entirely obtained by distilling the young shoots and leaves of the trees. Its odour is less delicate than that of neroli oil, to which it is frequently added as an adulterant. It is used in the manufacture of *Eau de Cologne* and other scents.

Lemon Grass Oil.—This oil is prepared, chiefly by native methods of distillation, from the grass of that name (*Andropogon citratus*), which grows extensively in different parts of India, Ceylon, and the West Indies.

It is a yellow or yellowish-brown mobile liquid, with an odour resembling that of verbena, whence the oil is sometimes described as *oil of Indian verbena.* It is largely employed in the manufacture of perfumes and of scented soap, and is also one of the chief sources of the compound citral used in the manufacture of *ionone* or artificial violets.

Apart from these legitimate uses, it is frequently employed to adulterate lemon oil.

Citronella Oil.—The so-called " Indian grass " (*Andropogon nardus*), which covers extensive tracts in Ceylon, yields, on distillation with steam, an essential oil, which owes its name to the fact that it contains a large proportion of the compound citronellal. This oil, being exceedingly cheap, is used in enormous quantities for scenting common soaps, and in the manufacture of coarse scents, and is also added as an adulterant to more expensive oils.

In order to prevent the native workmen from stealing the oil, the distillate issuing from the condensing coil

is conducted into a vessel contained in an underground chamber, the door of which can be kept locked.

Verbena Oil.—Much of the oil sold under this name is really lemon grass oil, which, as was mentioned above, has a pronounced odour of verbena. The chief species of the plant originally used as the source of oil, and still distilled to a limited extent in Grasse, were *Verbena triphylla* and *V. officinalis*. The leaves of the former yield about 0·08 per cent. of a light yellow essential oil, the odour of which is more delicate than that of lemon grass oil.

Allusion has already been made to the variations that take place in the proportion of oil and in its distribution in different parts of the plant during its growth, and to the consequent advantage gained by distilling the leaves before the blossoming period.

Oil of Bay.—The leaves of the bay plant, *Pimenta acris*, which grows in the West Indies, yield, on distillation, from 2 to 3 per cent. of an essential oil with a characteristic aromatic odour. This oil enters into the composition of many commercial perfumes, and, in particular, is the scent-giving constituent of the hairdresser's *bay rum*. The commercial product is liable to be adulterated with oil of cloves and oil of pimento.

Oil of Jasmine.—The oil derived from the blossoms of the jasmine (*Jasminum grandiflorum*) is usually sold in the form of the *jasmine pomade* prepared by the method of *enfleurage*. The oil in the flowers is present in so minute a quantity and is so volatile, that the ordinary distillation methods of separation are unsatisfactory and expensive.

In the South of France, however, a small amount of the oil is prepared by extracting the blossoms with petroleum spirit, and evaporating the solvent at a low temperature.

The yield of oil thus obtained is only about one-ninth of that extracted by fats in the *enfleurage* process, and on these facts a theory has been based, that in flowers such as the jasmine and the tuberose, there is a constant formation and volatilisation of the perfume, whereas in flowers such as the rose a large proportion of the essential oil accumulates in a ready-formed condition in the cells. Hence on treating the petals of the jasmine with moist fat the cells are not immediately killed, and the process of scent-formation still continues, while distillation or treatment with petroleum spirit immediately inhibits this vital process. This theory has been called in question by several critics, who suggest that the smaller yield may also be explained by the fact that petroleum spirit extracts less essential oil than fat, and that in the evaporation of the solvent there is inevitable loss of the oil.

The jasmine oil obtained by the extraction method is a pale brown mobile liquid with a pleasant odour, which is quite distinct, however, from that of jasmine pomade.

Alcoholic extracts of the pomade are used in the preparation of scents, their chief value being to give freshness to mixtures of other perfumes which lack that quality.

The essential oils of the *tuberose*, *jonquil*, *hyacinth*, *violet*, etc., are, like oil of jasmine, chiefly known in the form of pomades obtained by *enfleurage*, or in alcoholic extracts of those pomades.

Oil of Orris.—In Tuscany and other parts of Italy large areas are given over to the cultivation of three species of *iris*, *Iris florentina*, *I. germanica*, and *I. pallida*, the roots of which when dried and powdered have a delicate odour of violets, and are widely used in the preparation of the *violet powders* of commerce.

These plants are also cultivated in other parts of Europe, in Morocco, India, etc., but Italy is still the chief source of supply.

The so-called *Florentine orris*, by which in commerce is understood the roots of all three species, derives its name from being grown in the neighbourhood of Florence, and is the most valued. The roots grown near Verona are also held in high repute, especially in the United States. Of late years, however, the cultivation at Verona has steadily declined, owing to the low prices resulting from over-production of orris root in other places, and the increasing manufacture of artificial violet perfume from lemon grass oil. Thus, in 1905, the annual output, which only a few years before had been 600 tons, had fallen to 80 tons.

The fragrant violet odour of orris is not perceptible in the freshly-gathered roots, but gradually develops in them after drying, probably through some chemical process analogous to that which takes place in the development of the odour in oil of almonds.

The earliest *essences of violets* consisted of alcoholic extracts of the powdered root, but as these also contained inert substances simultaneously extracted from the root, they lacked the purity of odour of a solution of the essential oil.

The substance obtained by distilling powdered orris root with steam consists of a semi-solid mixture of the essential oil and fatty constituents of the root carried over mechanically. By subsequent treatment the solid inert parts may be separated, leaving a liquid volatile oil in which is concentrated the violet-scented constituents of the root. This product has an intense and extremely delicate odour of the fresh violet and fetches a high price in the market. It is used commercially in the preparation of the finest scents, and is also

blended with artificial violet perfumes prepared from lemon grass oil, the odour of which it renders more subtle.

Costus Oil.—Another essential oil, with a delicate perfume resembling that of violets, is that distilled from the roots of *Aplotaxis Lappa*, which grows in India, and is sold under the commercial name of *costus oil*. It is used for the most expensive kinds of perfumes, and fetches nearly as much in the market as fine oil of orris. When kept, its odour may become unpleasant, but a secret process has been devised by Messrs. Schimmel & Co. to prevent this change, which is probably the result of atmospheric oxidation.

Patchouli Oil.—The essential oil sold under this name has a characteristic persistent odour, and is now chiefly used in the preparation of the coarsest kinds of scent. It is derived from the dried leaves of *Pogostemon patchouli*, a plant which is cultivated in the Straits Settlements, in Java, Mauritius, and in other parts of the East.

Formerly the whole of the commercial oil was distilled by the natives, and a considerable quantity is still separated on the spot; but, owing to the systematic adulteration, most of the oil now sold is distilled in Europe from imported leaves.

The colour of the distilled oil ranges from dark yellow to greenish brown or brown, the differences being probably due to climatic influences upon the plant.

Many of the oils yield, on re-distillation, bright blue distillates, owing to the formation of a blue compound, "azulene," during the process. A substance termed *patchoulene*, with a strong cedar-like odour, has been separated from the oil.

Patchouli oil is frequently adulterated with cedar

wood oil and oil of cubebs, and occasionally with turpentine.

Cassia Oil.—The leaves and green twigs of the cassia plant (*Cinnamomum cassia*), the bark of which furnishes the well-known spice, contain over a half per cent. of essential oil, which is separated by the most primitive methods in Chinese distilleries. The plant is also cultivated in India, the East Indies, and the Philippine Islands, but the production of the oil is also exclusively in the hands of the Chinese.

The leaves and green shoots used for the distillation are stripped from the shrubs during the summer, and boiled with water in large iron vessels. The resulting aromatic decoction is then distilled to separate the essential oil from the aqueous portion.

The greatest secrecy is maintained by the Chinese on the subject of the cassia plantations and stills, and every obstacle is placed in the way of Europeans who wish to gain information about them. An interesting description of the difficulties encountered by the representatives of a German firm in Hong-Kong, and of the way in which they overcame them is given in one of the reports of Messrs. Schimmel & Co., the well-known distillers of essential oils.

The still which is used in the numerous small distilleries consists of an iron pan fixed over a square brick fireplace. On this pan rests a wooden cylinder lined with iron, and the joint between the two is tightly closed with wedges of moistened cloth. Round the outside of this cover near the bottom runs a hollow groove which is kept filled with cold water to condense the vaporised oil, and the latter falls into another narrow groove within the cover, and is then conducted by a tube into a series of tin cans placed at a level below the still. The principle employed is thus identical with that

utilised in the modern "Gem" still, for obtaining distilled water over an ordinary fire.

The oil derived from the leaves is greater in quantity and of better quality than that yielded by the mixed leaves and twigs. The bark used as the spice contains about twice as much essential oil as the leaves, but is too valuable to be used for this purpose.

The oil thus obtained is packed in tins and sent to Hong-Kong for exportation to Europe. The residual twigs and leaves from which the oil has been removed are dried and used for fuel.

Pure oil of cassia leaves is a heavy fluid with a sweet taste and an aromatic odour of cinnamon, the oil of which it is therefore sometimes used to adulterate.

The commercial product is systematically adulterated by the Chinese, various resins, including colophony, castor oil and petroleum oil being among the substances used for the purpose.

The chief commercial use of the oil is in the perfumery industry.

Cinnamon Oil.—The true oil of cinnamon is obtained from the bark of the spice plant, *Cinnamomum zeylanicum*, which grows in India, the West Indies, and many other places in the East, but is chiefly cultivated in Ceylon. Most of the bark is too valuable as a spice to be used for this purpose, and the oil is therefore distilled from broken fragments and chips of the poorer qualities of bark. These pieces are soaked in brine for a few days before distillation to loosen the ligneous tissue, and are distilled in native stills, a yield of a little less than one per cent. of oil being eventually obtained.

Cinnamon oil is slightly heavier than water, and has a characteristic delicate aroma of the spice. It is largely employed in the manufacture of scents and as a flavouring agent, and is also an official drug in the British

Pharmacopœia. It is liable to be adulterated with cassia oil, which has a similar but more pungent odour. Clove oil and the oil distilled from the leaves of the cinnamon plant are also used as adulterants of cinnamon oil.

Cinnamon Leaf Oil, which is present in the leaves to the extent of about two per cent., is also an important commercial product, being a common constituent of many perfumes. It differs considerably both in composition and odour from the bark oil, and fetches a much lower price in the market. It contains a large proportion of *eugenol*, which is the characteristic constituent of oil of cloves.

Sassafras Oil.—Among the essential oils most extensively used in the manufactures of the coarser descriptions of perfumes, and especially for scenting the cheapest grades of soap, a leading place is taken by the oil distilled from the bark of the roots of the sassafras tree (*Sassafras officinale*). This tree grows extensively in various parts of America, from Virginia to Canada, and in the Southern States often attains a height of 80 to 100 feet.

The roots, the smaller of which give the greater yield of oil, are dug out and distilled by primitive methods of steam distillation, many of the stills being worked by the negroes.

A form of apparatus in common use near Baltimore consists of a wooden tank provided with a perforated false bottom upon which the material is placed, and a copper head connected with a condensing coil immersed in cold water.

Steam under pressure is introduced beneath the false bottom, and passing through the perforations, extracts and carries forward the oil in the root. The condensed products issuing from the coil are conducted to the

bottom of large copper vessels, where they separate into two layers, of which the oil being the heavier is beneath, while the water overflows from the top. A yield of 8 per cent. or more of oil is thus obtained from good roots.

The oil derived from the leaves of the tree differs in composition and odour from the root oil. The latter contains, as its chief active constituent, a substance termed *safrol*, which is also an important constituent of camphor oil. Large quantities of safrol are now prepared from camphor oil, and used as substitutes for sassafras oil, and, being cheaper than the latter and equally effective as perfuming agents, have had an appreciable effect upon the commercial value of the natural product.

Oil of Veti-Vert.—This oil, which also goes by the name of *cuscus oil*, is derived from the roots of a species of grass (*Andropogon muricatus*), which grows extensively in India and the West Indies. In Bengal the grass is termed *Khas-Khas*, and the English name is obviously a corruption of the native word. The oil has a very pronounced characteristic odour, and is blended with other oils of more delicate aroma, in the manufacture of exquisite scents. It is frequently adulterated with cheaper essential oils, and sometimes with fatty oils.

Bergamot Oil.—This oil is extensively used in perfumery, and to a smaller extent as a flavouring agent. It is obtained by expression from the rind of fruit of a species of *Citrus*, *C. bergamia*, the bergamot tree, which is cultivated for this purpose in various localities in Calabria in Southern Italy, and notably near Reggio.

Formerly the process of expression was carried out by hand, as is still done in obtaining the oil from lemon

peel, but this method is now rarely used, its place having been taken by a rapid mechanical method.

In the type of apparatus that has been employed for many years the round fruit is introduced into a saucer-like cavity, the surface of which is covered with radiating knife-edged grooves. The fruit is pressed against these and made to revolve rapidly by means of a close-fitting cover, which is actuated by a cog-wheel. The oil exuding from the ruptured cells falls through perforations in the cavity and collects in a vessel placed underneath.

It is allowed to stand for some time, until the bulk of what is known as *bergamot camphor* has deposited, and is then bottled and exported.

As thus obtained bergamot oil is a limpid fluid, with a pronounced aromatic lemon-like odour, and a yellowish green colour due to dissolved chlorophyll. Rectification of the oil by further distillation will yield a colourless product, but does not increase the fragrant odour.

Inferior grades of oil are prepared by mixing the expressed rinds with the rasped and partially exhausted peel of unripe fruit blown from the trees (termed *Nero of bergamot*), and distilling the mixture. The distillate is frequently added to the expressed oil in order to obtain a cheaper product.

Oils of this type are particularly liable to be met with in commerce after a season in which very hot dry weather follows immediately upon the flowering period. Under such conditions the fruit does not settle properly and immense quantities drop from the trees in an immature condition. This kind of oil differs from ordinary bergamot oil in containing a smaller proportion of the ethers to which the oil owes its aroma, and its odour is therefore inferior. A method of estimating the proportion of ethers is employed in detecting the

substitution of this lower grade of oil for the genuine product.

The chief adulterants of commercial bergamot oil are oil of lemon, oil of orange, turpentine, and fatty oils, the last being readily detected by the adulterated oil leaving a fixed residue on evaporation.

The principal odoriferous constituent of bergamot oil is the ether, linalyl acetate. This is also prepared by synthetical methods, and sold as a competitor of bergamot oil. The price is considerably higher, but it is claimed that the odour of the artificial product is more than proportionately superior to that of the oil.

Terpeneless Oil of Bergamot, in which by separation of the terpenes the odour has been intensified, are also on the market. It is claimed that the aroma of these is three times as strong as that of the ordinary oil.

Ylang-Ylang Oil.—The delicately scented essential oil known as oil of cananga or oil of Ylang-Ylang, a name which signifies " flower of flowers," is obtained from the blossoms of *Cananga odorata*, a tree which grows wild and is extensively cultivated in different parts of South Asia.

The largest proportion of the commercial product is derived from the Philippine Islands, where the climate and soil are particularly suitable to the cultivation of the tree. The flowers are distilled in a very modern type of apparatus in Manila, and a large and increasing export trade in the oil is carried on with the United States and with France.

About 75 lbs. of the flowers are required to produce 1 lb. of the oil, and this fetches from 40 to 55 dollars in the American market.

Ylang-Ylang oil is a strong competitor of otto of roses, and is used in the United States as the basis of some of the most delicate and expensive perfumes. The

supply of the Philippine oil is, as yet, unequal to the demand. A certain proportion of the oil is also obtained from Java, but cannot compete with the Philippine oil in delicacy of aroma. The two oils also appear to differ in constitution, which may be the result either of climatic influences upon the tree or of different methods of distillation.

The commercial oil is not infrequently adulterated with a fatty oil, the result of which addition is to render the oil less soluble in spirits of wine, and to cause it to leave a fixed residue on evaporation.

A synthetical ylang-ylang oil, the odour of which is very similar to that of the natural product, is also used by the manufacturers of perfumery.

Linaloe Oil.—There is some confusion with regard to the nature of the essential oil commercially known as *linaloe* or *lignaloe oil*. The commercial product is not, as its name indicates, distilled from the wood of aloes, but is obtained from the wood of trees belonging to the natural order *Burseraceae*, which are found in Mexico. The wood is distilled on the spot and is also exported and distilled in Europe. It yields about 10 per cent. of a light oil with a fragrant odour somewhat recalling that of bergamot oil.

The wood termed *lignaloe* in Brazil and French Guiana yields, on distillation, an essential oil, which is frequently described as *Essence de bois de rose femelle* to distinguish it from linaloe oil, although it is no more connected with rosewood than it is with aloes, being in fact derived from the wood of a tree belonging to the natural order *Lauraceae*. Its odour is more delicate than that of linaloe oil, and it fetches a considerably higher price in the market.

The confusion between these two oils is still further increased by the fact that a genuine *oil of rosewood* is

also a commercial product. This is obtained from the wood of certain kinds of *Convolulaceae* growing in the Canary Islands. It is a thick light yellow fluid, with an odour somewhat reminiscent of otto of roses. It is also known as *rhodium oil*.

Thyme Oil.—Two varieties of thyme oil are distinguished in commerce, viz. : red and white oil of thyme, the latter being the more valuable. Both are obtained by the distillation of the common thyme, *Thymus vulgaris*, the red oil being the first distillate and yielding on rectification the " white " oil.

According to Parry it is probable that the colour of the " red " oils is due to the action of certain constituents (phenols) upon the iron of the stills and condensers.

The oil from another species of thyme, *Thymus serpyllum*, is often mixed with that from *T. vulgaris*. This oil has a somewhat different odour, and the mixed product is less valuable than that derived from the common thyme only.

A large proportion of the commercial supply of oil is distilled in the South of France, and the French oils now fetch a higher price than the Spanish oil of thyme, which, a few years ago, had the greater reputation. The dried plant yields between 2 and 3 per cent. of oil.

Oil of thyme is used in the manufacture of cheap perfumery and for scenting soaps. It is sometimes sold as *origanum oil*, owing to the fact that the essential oils distilled from various species of *Origanum* (*true origanum oil, marjoram oil, sweet marjoram oil*) have a somewhat similar odour and composition, and are very much more expensive.

Oil of turpentine is the most common adulterant of oil of thyme, and another fraudulent practice consists in abstracting a portion of the constituent termed *thymol*, to which the oil mainly owes its value.

It is therefore usual to base commercial transactions upon the proportion of thymol and allied compounds in the oil, and against the best qualities of this oil in the manufacturers' lists will be found statements that they contain from 25 to 30 per cent. of phenols. The thymol abstracted from the oil can be sold separately for a good price.

Oils of similar composition and odour may be distilled from other species of thyme, such as *Thymus camphoratus* and *Thymus capitatus*, while a variety termed *T. citratus* yields an essential oil with an aroma more like that of lemon thyme than that of ordinary thyme.

Oil of Myrrh.—Myrrh is the dried juice that exudes from the bark of several species of shrubs of the genus *Commiphora*, which grow wild and are also cultivated in various localities bordering on the Red Sea, and especially in Arabia and Somaliland. On distillation this gum yields a thick oil of a yellowish green colour and with a strong aroma of myrrh. The distilled oil is mentioned in the drug ordinances of Frankfurt of 1587.

Bisabol oil of myrrh, which is distilled from the bisabol myrrh, *Commiphora kafal*, grown in Somaliland, has a different odour from that of ordinary myrrh oil.

Opoponax Oil.—The oil of opoponax now sold is stated by Holmes to be identical with bisabol myrrh oil, and is not, as its name indicates, any longer derived from the plant *Opoponax chironium*. The myrrh resin yields on distillation from 6 to 10 per cent. of a greenish-yellow oil, with a fragrant odour of balsam.

Frankincense Oil.—This oil, also known as *Olibanum oil*, is derived from the gum resins of *Boswellia* plants, the yield being on distillation with steam from 3 to 8 per cent. This oil is also mentioned in the Frankfurt drug ordinances of 1587 under the name of *oleum thuris*.

It is a colourless or pale yellow fluid with a fragrant balsamic aroma.

Artificial Perfumes.—If we except the manufacture of aniline dyes from coal tar, there is perhaps no industry in which chemical research has succeeded in producing so many synthetical compounds that would compete more or less satisfactorily with the natural products than has the manufacture of artificial perfumes. Long years of laborious work in isolating the individual constituents of different essential oils and ascertaining to which of them the characteristic odour of each oil was due have justified the attempts to isolate or to build up these compounds from other materials, and in some cases the resemblance has been so close that the artificial perfume has more or less displaced the natural one.

As was mentioned before, it is only in exceptional cases that an essential oil consists practically of a single constituent in an approximate state of purity, but in the best example of this kind the artificially prepared compound has proved a serious commercial competitor of the natural oil. Formerly oil of wintergreen was distilled in large quantities from the herb *Gaultheria procumbens*, but the bulk of the commercial oil now sold at a sixth of the cost of the natural product consists only of chemically-prepared methyl salicylate, and for many purposes is quite as effective.

As a rule, however, the problem to be solved has been of a more complex character, for even when the fragrant aroma of a flower or fruit has been traced to certain definite chemical compounds in the essential oils it by no means follows that the other constituents, although apparently inert as regards the odour, do not in fact tend to modify the aroma of the scent-bearing substances with which they are associated. This probably explains

why some of the artificial scents in the market are so much coarser in odour than the natural perfumes.

In other cases the most important odoriferous constituent may have been identified, while other substances which also contribute to the total aroma may have escaped identification, so that the artificial perfume is thus an imperfect blend, which while recalling the odour of the natural product, yet differs materially from it.

Safrol.—Perhaps the most successful imitation of one perfume by a substance prepared from another essential oil is to be seen in the compound safrol, which has to a large extent displaced the natural oil of sassafras. As soon as it had been discovered that safrol, the active constituent of sassafras oil, was also an important constituent of oil of camphor, preparations of the latter oil in which the safrol had been concentrated by fractional distillation were put upon the market. These are still sold as substitutes for sassafras oil, but are decidedly inferior in odour, the safrol aroma being masked by the other constituents left in the camphor oil. Subsequently the safrol was separated in a pure state and is now sold under the name of "artificial safrol" in enormous quantities for scenting soaps in which formerly sassafras oil was used. The cost of the artificial perfume is only about a third of that of the genuine essential oil, and is quite as good in its aroma.

Artificial Heliotrope is another synthetical perfume for which safrol also serves as the primary base. On oxidising safrol under suitable conditions it is transformed into a compound termed *heliotropin*, which has a pronounced odour of heliotrope flowers. Most of the numerous heliotrope perfumes on the market consist of alcoholic solutions of this compound blended with other compounds, such as coumarin, vanillin, or acetanilide.

Coumarin, the scent-bearing constituent of Tonka beans, is a crystalline compound which is obtained commercially by a series of chemical reactions from salicylic acid. It has the strong aromatic odour of the bean, and is used, generally in admixture with other compounds, in producing various artificial scents such as *new-mown hay*.

Vanillin, the compound to which the vanilla pod owes its fragrance, is a substance which crystallises in minute white needles. It can be prepared from various compounds, but the chief source of the commercial product is *eugenol*, the principal constituent of oil of cloves. Vanillin is extensively employed for blending with other scents in perfumery, but its chief use is to give a vanilla flavour to confectionery. When first prepared in 1876 it was quoted at £160 per lb., but owing to improved and cheaper methods of manufacture and the stress of competition, its price has steadily fallen, until at the present time it can be bought at 16s. per oz.

Artificial Lilac usually contains as its main constituent the compound *terpineol*, which is prepared by various chemical methods from ordinary oil of turpentine. The pure substance has a delicate odour of lilac and when blended with other compounds can also be used in the production of hyacinth and other flower scents.

Bergamiol, the commercial substitute for bergamot oil, is the name given to the chemical compound linalyl acetate, to which the odour of the natural oil is mainly due. It is prepared synthetically by the interaction of linalol and acetic acid.

Neroli.—In preparing scents the odour of which in the flower is made up of several constituents, as in the case of neroli oil, mixtures of several compounds are blended together to imitate as far as possible the composition of the natural product. Obviously it is much more

difficult to prepare a passable perfume of this type than one in which the aroma is inherent in a single substance, since every variation in the proportions of the several ingredients has its influence upon the odour. The delicacy of aroma also depends upon the purity of the compounds, and hence a good synthetical oil of neroli costs at least a third of the price of the genuine oil.

Artificial Rose Oils are, at best, only poor imitations of genuine " otto " of roses. They are generally made up from the two chief constituents of the natural oil—geraniol and citronellol—separated from cheaper essential oils. They lack the delicacy of the rose perfume, and it is not an uncommon practice to add to them a trace of the genuine " otto " of roses to mask the deficiency.

Artificial Violet.—The most valuable of all the synthetical perfumes are probably those compounds which are now extensively used as substitutes for the scarce and expensive oil of violets. They were first prepared commercially in 1893 by Tiemann, who took out a patent for the manufacture of a compound termed *ionone*, having the odour of violets, and prepared by a series of chemical reactions from *citral*. As has been mentioned, a cheap supply of citral is available in lemongrass oil, and the demand for it has enormously stimulated the production of that oil.

In its pure and concentrated state ionone has not a violet odour, but this is developed to a pronounced extent when the substance is dissolved in dilute alcohol. For this reason ionone, of which large quantities are manufactured by Messrs. Schimmel & Co., is usually sold in a 10 or 20 per cent. solution in rectified spirits of wine. With reference to complaints occasionally made that ionone has no odour at all or that it even has a disagreeable smell, Messrs. Schimmel & Co. state that this is solely " due to a blunting of the olfactory nerves, or

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A PEPPERMINT HARVEST IN MICHIGAN

more correctly to a nasal delusion, which also occurs sometimes in the case of other flower odours, and to which people are known to be particularly liable when smelling freshly-gathered violets."

"The principal thing in connection with the employment of ionone is to discover its proper degree of dilution. In using it for extracts, powders, etc., the solution must be further diluted and fixed with some orris oil, civet and musk."

Genuine "otto" of violets from the flowers is worth about 45s. per oz., while a 20 per cent. solution of ionone costs only about 6s. per oz. The artificial perfume has a much more penetrating odour than the natural oil, but in the opinion of most perfumery specialists is inferior in delicacy of aroma.

Artificial Musk.—None of the numerous attempts made to imitate the natural musk, secreted by the musk deer, appear to have met with any measure of commercial success until, in 1889, Baur claimed a process for the manufacture of a nitrated hydrocarbon from toluene, to be used as a musk substitute.

This compound, which is sometimes described as "musk Baur," is a crystalline substance, which is soluble in alcohol, and, on the addition of a small proportion of ammonia, emits a pronounced odour of musk. This substitute for the natural scent is employed to a considerable extent for scenting soap and in the manufacture of the coarser grades of perfumes. In the pure crystalline form it is sold at about 10s. a lb.

Artificial Hawthorn.—The oily compound which is sold under the name of *Aubépine*, is, in chemical nomenclature, anisic aldehyde. It may be obtained either by oxidising aniseed oil or by a more complicated process from phenol (carbolic acid). When purified by distillation it has a very fragrant odour of hawthorn, and

is used as the basis of many of the commercial *may blossom* scents. It is also blended with other compounds or with natural essential oils to imitate other flower perfumes. When exposed to the air it is gradually oxidised to anisic acid, and it is therefore essential to keep it in tightly-closed bottles, which are also kept filled to exclude air. Otherwise it will become useless for perfumery purposes. Aubépine is sold at the present time at about 25s. per lb., and a crystalline preparation intended for scenting toilet soaps and containing a large proportion of the pure substance, can be obtained at a lower price.

Volatile Oils Used as Flavouring Agents

The oils that may be classified under this heading include all those used in the manufacture of liqueurs and mineral waters, in confectionery, and for purposes of cooking. Some of them, such as oil of lemon and oil of cloves, are also used to a less extent as drugs, and in perfumery in making compounded scents, and are employed fraudulently to adulterate expensive essential oils from flowers.

Oil of Peppermint.—Peppermint oil is obtained by distillation of the peppermint plant, several species of which are cultivated for the purpose.

In England the medicinal properties of the plant were first recognised about the beginning of the eighteenth century, and it then became an official drug in the London Pharmacopœia.

Two varieties of *Mentha piperita* are cultivated, the "white" mint more extensively than the "black" mint, since it is believed to yield an oil of more delicate aroma. The principal peppermint fields are near Mitcham, in Surrey, at Hitchin in Hertfordshire, and

near Market Deeping in Lincolnshire. Up to 1805 the distillation was carried out in London, but subsequently was transferred to Mitcham and other localities nearer the peppermint fields.

About the middle of last century the competition of the rising American peppermint industry began to make itself felt, and English peppermint no longer retained its complete control over the market. The English method of distillation is by means of stills provided with false bottoms, upon which the peppermint is placed. Water is also introduced and the still sheated over a fire.

Peppermint was first distilled in America in Wayne County, New York, by a method similar to that still employed in this country. This method was largely superseded about 1846 by the use of wooden tanks for stills. These vessels are covered with metal heads connected with condensers, and the oil is carried over by a current of steam admitted under pressure.

The chief peppermint areas under cultivation in America are in the States of New York, Indiana, and Michigan, which produces by far the largest proportion of the commercial American oil.

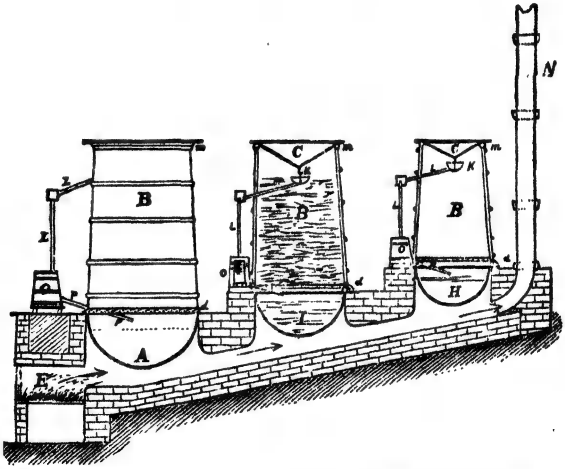
The cultivation of peppermint in Thuringia has gradually declined, but a new industry has sprung up near Leipsic, and this German oil, distilled by the most modern methods, has a very fine aroma and fetches a high price in the market.

A small amount of oil is also distilled in Russia and in Italy, but is consumed in the country of its production.

The chief peppermint-producing country in Asia is Japan, where extensive areas are under cultivation, mainly in the island of Hondo, and especially in the province of Uzen. The plant there cultivated is a variety of *Mentha arvensis*, which produces an oil

differing both in properties and composition from the English and American oils.

The Japanese apparatus, a description of which has been given by Mr. E. Marx, consists of three iron boilers, A, I, H, on which rest wooden vats, B, with perforated bottoms, on which the peppermint is placed. The steam penetrating through these permeates the herb and carries the volatile oil to the top, where it meets condensers, C, containing water. The condensed product falls into the small suspended cups, K, and the water separating from the oil runs back through the bamboo tubes, L, into the boilers again. When the water in



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the condensers, C, becomes hot, it is drawn off by means of a bamboo siphon and replaced by cold water. Should the boilers become overheated the products from the

burning straw with which the fires are fed may find their way into the distillate, and to this may be attributed the peculiar burnt flavour sometimes to be noticed in Japanese peppermint oils.

Peppermint oil is also distilled in China, near Canton, from a variety of the same plant used in Japan.

Apart from differences due to the different species of the plant, the soil and climate have a great influence upon the properties of the essential oil, and the best Mitcham oil is considered so superior in flavour to the American oil distilled from the same plant that it fetches from four to five times the price in the market. The finest Japanese oil is usually sold at about the same price as an average American oil. The differences in flavour of the peppermint oils of different origin are so pronounced that a trained specialist can distinguish between Japanese, American and English oils by their odour and taste.

The American oil may also be distinguished from the other two oils by its smaller solubility in alcohol. In some cases a bluish fluorescent tint is produced, due to a chemical action started by light, and this reduces the value of the American products.

The different oils vary in composition as well as in flavour, and contain different proportions of the characteristic compound *menthol*, and of ethers. The relative amounts of these constituents are influenced by the stage of growth of the plant, the menthol, which is the more abundant at an early period, gradually decreasing, while the ethers increase, and reach their maximum when the blossoms are formed.

The delicacy of aroma evidently does not depend entirely upon the proportion of menthol, since English oils, which contain about 60 to 70 per cent., are infinitely superior to the Japanese oils, which are particularly

rich in that compound, usually containing from 70 to 80 per cent., and sometimes more.

As menthol is a valuable commercial drug, it is a common practice to remove the whole or a part of it from Japanese peppermint oils by a freezing process, which causes the menthol crystals to separate. The dementholised oils are sold as such at a lower price, or are used to adulterate untreated oils containing a high percentage of menthol. As a rule about 35 per cent. of menthol is left in the commercial "dementholised" peppermint oils. A completely dementholised product has but little commercial value.

Ordinary oil of peppermint is colourless or of a pale yellow colour, and has an aroma that improves on keeping. It is very extensively used in confectionery, in making liqueurs, and in pharmacy.

In addition to the fraudulent abstraction of menthol and the substitution of blends containing foreign oils for English oils, adulteration of peppermint oil with other substances, such as turpentine oil, is not uncommon. Chemical examination will detect the grosser forms of fraud, but in the case of skilfully prepared blends of oils of different origin greater reliance must be placed upon the judgment of the skilled palate.

Spearmint Oil.—The largest proportion of the commercial oil is obtained from America, where it is distilled in the States of New York and Michigan from the herbs *Mentha viridis* or *M. crispa*. The oil is also prepared in Germany and in Russia, but the species of plant yielding the Russian commercial oil is not known. A small amount is distilled at Mitcham, and the English oil is sold at about five times the price of the American product.

Spearmint oil is colourless or greenish-yellow, and has the characteristic odour of the plant. It is used to a

limited extent for flavouring purposes and in perfumery, and is an official drug in the British Pharmacopœia.

Oil of Cloves.—This important commercial oil is distilled from the unopened blossoms of the clove tree (*Eugenia caryophyllata*), an evergreen plant, originally a native of the Moluccas, but now cultivated in Mauritius, Penang, Madagascar, and especially on the islands of Zanzibar and Pemba, which supply about four-fifths of the world's demand for cloves.

The oil was distilled before the fifteenth century, and is mentioned in the drug ordinances of Berlin of the year 1574.

Most of the commercial oil is distilled from dried Zanzibar cloves, for although the cloves from Réunion are richer in oil they fetch a better price as a spice. Zanzibar cloves yield from 15 to 18 per cent. of oil. A small proportion of oil is also distilled from Amboyna cloves (Moluccas), and being superior in aroma have a considerably higher value for purposes of perfumery than the ordinary oil.

Clove oil is nearly colourless or pale yellow, but darkens on keeping. It has the characteristic aromatic odour of the plant, and a pungent burning taste.

When distilled, part of the distillate, being heavier than water, sinks to the bottom, while the remainder floats on the surface, and these two fractions when united form the oil of commerce.

The chief constituent of clove oil is a substance termed *eugenol*, and a good sample should contain from 70 to 85 per cent. of this constituent.

The oil distilled from the stems of the plant is of similar composition, but its aroma is not so good as that of clove oil.

The chief uses of oil of cloves are for perfumery, and in the manufacture of liqueurs and aromatic vinegar.

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CUTTING PEPPERMINT

It is also employed to a small extent in pharmacy, and is an official drug in the British Pharmacopœia.

It is liable to be adulterated with oil of turpentine and petroleum oil, with copaiba and gurjun balsams, and with other essential oils such as cedar-wood oil. In addition to these adulterations the eugenol is sometimes fraudulently abstracted and sold for the manufacture of vanillin, and the residual oil passed off as a genuine product. The separated eugenol fetches a higher price in the market than the original oil. All these frauds may be detected by chemical examination, and especially by an estimation of the proportion of eugenol in a given sample.

Pimento Oil.—The small berries of the evergreen plant, *Pimenta officinalis*, which grows extensively in the West Indies, and especially in Jamaica, are collected before they are ripe and sold as a spice under the name of *pimento* or *allspice*. The latter name is obviously due to the odour recalling that of several other spices, though an odour of cloves predominates.

On distillation, the spice gives about 3 to 4 per cent. of a heavy oil of red colour and with the same aroma as the berries. This oil resembles clove oil in containing a high percentage of eugenol, and to this compound it owes the suggestion of cloves in its aroma.

As in the case of clove oil the eugenol and other constituents are sometimes abstracted, leaving a "dephenolised" oil, which is much lighter than the genuine product.

Pimento oil is used in the manufacture of liqueurs and spiced British wines, and is also an official drug in the British Pharmacopœia.

Ginger Oil.—The dried root or rhizome of the ginger plant, *Zingiber officinale*, which is cultivated in Asia, the West Indies and Africa, yields when distilled about

A VANILLA VINE

3 per cent. of a yellow oil with the well-known pungent aroma.

The oil is used to a considerable extent in the manufacture of ginger wine and liqueurs, though "essences" consisting of alcoholic decoctions of the root are perhaps more frequently employed. A *terpeneless* oil of ginger is also on the market. The nature of these oils has already been described on a previous page.

The chief adulterant of soluble essences of ginger is an extract of capsicums which gives heat without flavour.

Oil of Lemon.—The main supply of this essential oil is derived from Sicily, Italy, and the South of France. It is contained in the peel of the fruit of the lemon tree, *Citrus limonum*, which is cultivated extensively in Southern Europe, and especially along the coasts of the Mediterranean.

For the most part, the oil is still extracted by hand, and machinery has not been adopted to any extent. There are a few large factories, numerous small ones, and innumerable families of peasants who squeeze the peel of the lemons grown in their own gardens.

The method of extraction used in Sicily and South Italy is the *Spugna*, or sponge, process. The lemons are cut into slices so that little pulp is left upon the peel. The pulp is pressed and the juice sold to the manufacturers of calcium citrate, which is exported, principally to England, and made into citric acid. The peel is squeezed against a sponge, which when filled with oil is expressed into a large vessel, and subsequently decanted from the aqueous layer and filtered through paper.

In the north of Italy and in the Riviera the oil is separated by the *ecuelle* process, in which the fruit is rolled about in a vessel studded with points, the oil

exuding from the ruptured cells being collected in a hollow space in the handle of the vessel.

The machinery which has been introduced into some of the Italian factories is constructed on the same principle as the manual extraction. The process is somewhat more rapid, but the oil extracted by machinery has not so good an aroma as that produced by hand.

The oil, by whichever process obtained, is stored and exported in cylindrical copper vessels lined with tin.

The proportion of oil given by the peel varies considerably with the season, the maximum being obtained between November and February, when 1,000 lemons yield from 1 to 2 (Italian) pounds of oil.

The immature fruit yields much less oil, and the quality and aroma of the product are also inferior.

A certain amount of oil of poor quality is also obtained by distillation, the expressed peel and unripe windfalls being used for the purpose. This distilled oil is frequently used to cheapen the genuine oil from fresh fruit.

The trade in lemon oil is in the hands of merchants and manufacturers, the principal market being at Messina. The variation in the composition and characteristics of genuine commercial oils may be attributed to those made in the winter from good lemons being kept separate from those made at other seasons from inferior fruit.

Such factors as the position of the gardens and the kind of season have also an influence upon the nature of the oil.

Oil of lemon is a light liquid of pale yellow colour, and with a strong aroma of lemon. It becomes paler on keeping, and is particularly liable to develop an unpleasant odour when exposed to light and air. For this reason it should be stored in vessels which are filled as full as possible and kept in the dark.

It is composed in the main of two terpenes termed *limonenes* and of the compound *citral*, which, as was mentioned before, is the chief constituent of lemon-grass oil. The oil exported from Sicily to England or America is often accompanied by a certificate of analysis stating the percentage of citral in the consignment. This single factor, however, is not a sufficient guarantee of purity, since a suitable addition of lemon-grass oil will increase the proportion of citral in an adulterated oil to the desired extent.

Oil of lemon is extensively used in confectionery, as a flavouring agent in pharmacy, in the manufacture of lemonade, and in perfumery.

A *terpeneless* oil of lemon is also on the market. This is prepared by distilling off under reduced pressure the greater part of the more volatile constituents (terpenes), and distilling the residue, which consists principally of citral, in a current of steam.

Adulteration of lemon oil is very widespread, and in the case of skilfully prepared blends is exceedingly difficult of detection. Turpentine has long been employed as a favourite adulterant, and the addition of a small proportion of orange oil makes the adulterated oil answer the requirements of the chief optical test.

It is significant that a mixture of 80 per cent. of lemon oil, 15 per cent. of orange oil, and 5 per cent. of turpentine is sold under a special name in Sicily.

Other fraudulent practices in connection with lemon oil are the admixture of old and distilled oils with freshly expressed oil, and the blending of the residual terpenes from the manufacture of terpeneless oils with suitable proportions of lemon-grass oil and turpentine.

Oil of Orange.—The oil extracted from the peel of the sweet orange, commonly termed *Essenza di portogallo*, is chiefly derived from Calabria and Sicily. It is

extracted by hand in the same manner as oil of lemon.

It has a pronounced yellow colour, and an aromatic but not bitter taste. It consists principally (about 70 per cent.) of limonene, and also contains citral. Its chief adulterants are oils of lemon and turpentine.

The oil from the peel of the bitter orange is known as *Essence d'orange bigarade.* It is not used to any great extent, and according to Fabris is not readily obtained in a pure condition. It is a yellow liquid with a bitter aromatic taste, and a more delicate aroma than the oil of sweet orange.

Both oils are used in confectionery, in the manufacture of liqueurs, and in perfumery. They are also sold in the concentrated form as *terpeneless* oils, and the waste terpenes from the manufacture are used to adulterate untreated oils.

Oil of Mandarin.—This oil, owing to its high price, is not often obtained pure in commerce. It is expressed from the peel of the fruit in the same manner as the oil of orange or lemon. It is a golden yellow liquid with a slight blue fluorescence, which becomes more pronounced on diluting the oil with alcohol.

Oil of Limes.—The bulk of the commercial oil of limes is obtained from the peel of the lime fruit, *Citrus medica*, var. *acida*, which is extensively grown, for the sake of its juice, in the West Indies, and especially on the island of Montserrat, where the cultivation forms the staple industry.

The method of expressing the juice from the peel has already been described, and a certain amount of an oil of inferior flavour is also prepared by distillation.

The oil of lime prepared in Italy is from the peel of a different fruit, *Citrus limetta*, and is expressed in the same manner as oil of lemon. It differs from the West

Indian oil in aroma, being more akin to bergamot oil, whereas the West Indian oil recalls the odour of lemons. It is commonly known as *limetta oil*, and is employed for flavouring purposes. The West Indian oil is extensively used in the manufacture of mineral waters, and in the preparation of the cheapest grades of lime-juice cordial, some of which contain no lime juice at all, but consist of coloured and sweetened solutions of tartaric acid flavoured with oil of limes.

Adulteration of oil of limes follows the same course as in the case of oil of lemon. Blends of various essential oil, including lemon oil (which is considerably cheaper) and turpentine are added to it, and in the cheapest products distilled oil is substituted for the expressed oil.

Oil of Bitter Almonds.—One of the most widely used flavouring agents is the oil prepared from the kernels of the seeds of the bitter almond tree, *Amygdalus communis*, var. *amara*.

After expression of the fixed oil from the crushed kernels the mass is mixed with water, and under the action of a ferment or enzyme termed *emulsin*, a compound known as *amygdalin*, which is present in the water, is gradually decomposed into benzaldehyde, a sugar, and prussic acid. After soaking for some hours the mass is distilled in a current of steam, great precautions being taken to prevent the poisonous prussic acid escaping into the air.

The oil thus obtained consists principally of benzaldehyde, though it also contains a considerable proportion of prussic acid. In some of the commercial oils, sold at a somewhat higher price, the prussic acid has been removed by chemical processes.

Oil of almonds is a heavy yellow liquid with a pronounced almond-like odour. Oils which are chemically identical with it are prepared from the kernels of apricots

and peaches, the latter oil usually being sold as *foreign oil of almonds.*

These oils, being much cheaper, are also fraudulently added to the genuine almond oil, and another common adulterant is artificial benzaldehyde, which is only worth about a seventh of the value. If the added compound has been carefully prepared the fraud can only be detected by a trained sense of smell.

Oil of almonds is also liable to be adulterated with the impure nitrobenzene, which is sold under the name of *essence of mirbane* for scenting cheap soaps, for which, however, its irritant action upon the skin renders it unsuitable.

The chief uses of almond oil are for flavouring confectionery, in medicine, and in perfumery.

Juniper Oil.—The berries of the common juniper tree (*Juniperus communis*) yield on distillation from 0·5 to 1·5 per cent. of an essential oil. The tree, originally indigenous to Greece, now grows in all parts of Europe, but the berries of the Italian shrub are those most valued and chiefly used for the distillation of the oil.

Juniper berries contain a large proportion of sugar, and decoctions of them are fermented in the manufacture of gin, the characteristic flavour of which is due to the essential oil.

Commercial oil of juniper is used in the preparation of artificial gin, which is little more than an alcoholic solution of the oil, and to a limited extent as a drug.

A so-called *juniper wood oil* is also on the market. This often consists of turpentine or of the residues obtained in the manufacture of terpeneless oils distilled over juniper berries.

Wormwood Oil.—The herb *Artemisia absinthium* yields, on distillation, from one-fifth to about one per cent. of green or bluish green oil, which is used in the

preparation of absinthe and other liqueurs, whence the oil is often termed *oil of absinthe.*

The plant is found in the northern countries of Africa, in various localities in Europe and Asia, and is also grown in the United States. The yield of oil obtained on distillation shows great variations with the period of growth, and, as was mentioned on a previous page, it is therefore advisable to gather the herb before blossoming begins.

Wormwood oil is also used to a limited extent in medicine. It is often adulterated with cheaper oils, and especially with turpentine oil, the presence of which may be detected by means of fractional distillation.

Aniseed Oil.—The greater proportion of the commercial aniseed oil is distilled from the star anise (*badiane*), *Illicium verum,* which is cultivated principally in the South of China ; but a considerable amount is obtained from the true anise, *Pimpinella anisum,* originally a native of Asia Minor, but now grown in many European countries, notably Russia, in India and in South America.

The oils derived from these two plants have many chemical points of resemblance, both containing as a main constituent the compound *anethol.* They are also very similar in their odour and other physical properties, but the Russian oil usually fetches a much higher price in the market.

Oil of aniseed is a pale yellow liquid, which is rather lighter than water, and solidifies at a little below the ordinary temperature (60° F.).

It is extensively used in the preparation of liqueurs and cordials, as a drug, and for blending with other oils in perfumery. It is frequently adulterated with petroleum oil and with oil of fennel, the Chinese or star aniseed oil being particularly liable to contain foreign substances.

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GATHERING BELLADONNA

The main constituent, anethol, is separated and sold as a commercial product, and the residual portion is sometimes used as an adulterant of the genuine oil.

Japanese star anise oil is an oil of quite a different odour from that of aniseed oil. It is distilled in Japan from the leaves of the herb, *Illicium religiosum*, and differs chemically from the other oils.

Volatile Oils Used as Drugs

Reference has been made to the use of many of the oils described in the two preceding classes for pharmaceutical purposes, and several of them are official drugs in the British Pharmacopœia. From a commercial point of view, however, their medicinal uses are subordinate to their employment as perfuming or flavouring agents, whereas the typical oils described in the present group are almost exclusively used in medicine.

Oil of Camphor.—Camphor and oil of camphor are obtained from the wood of the camphor tree, *Camphora officinalis*, which grows abundantly in Japan and China, and especially in the island of Formosa. The tree has also been planted in Ceylon and Florida, and small quantities of camphor are now derived from both these localities.

The method of collecting the camphor in Florida is of the crudest description, and immense quantities of the trees are destroyed in the process. After the tree has been cut down the smaller branches and twigs are placed in perforated jars covered with earthenware pots, and heated over boiling water. The steam penetrating the chopped-up wood expels the camphor, which is then condensed in crystals in the earthenware covers. On standing, a small proportion of oil separates from the crystalline part, and this is drained off and sold as oil of camphor. The bulk of this product, however, is

obtained by distilling chips of the wood with steam, the distillate consisting of a mixture of camphor and oil of camphor. This is redistilled so as to effect a separation of the two, the distillate then consisting chiefly of the oil, and the residue being camphor.

Strictly speaking, the commercial oil and the crystalline substance are the two fractions of the volatile oil from the wood, the ordinary camphor being analogous to the *stearoptene* which crystallises in rose oil and other vegetable essential oils. In commerce, however, a sharp distinction is made between the two camphor products.

The discovery by Messrs. Schimmel & Co. that safrol is an important constituent of camphor oil, and the use of that compound as a substitute for sassafras oil has given a great impetus to the industry. It is now a common practice for oil of camphor to be freed as completely as possible from safrol before it leaves Japan, and the residual *light camphor oils*, as they are termed, are sold at a much lower price, and are used as substitutes for turpentine oil. The value of oil of camphor thus mainly depends upon the proportion of safrol it contains, and the greater this quantity the heavier the oil.

Eucalyptus Oils.—It is only of recent years that the extensive trade in eucalyptus oils has sprung up, and the rapid growth of the industry is almost entirely due to the reputation that the oils have attained, as deodorants, antiseptics and curative agents generally.

The commercial oils are obtained by distillation of the leaves of numerous species of *Eucalyptus*, the principal supplies being derived from indigenous trees in Australia and from trees grown in plantations in Algeria and the United States.

The British Pharmacopœia, in which eucalyptus oil is an official drug, prescribes that it shall be the product

of *Eucalyptus globulus* or other species yielding an oil with similar chemical characteristics, and thus excludes the use of oils containing a smaller proportion of *eucalyptol* or *cineol*, or a greater proportion of the inactive constituent *phellandrene*.

It is to the eucalyptol that eucalyptus oil owes its germicidal properties, and hence many of the oils originally imported into this country, although the products of species of eucalyptus, had very little medicinal virtue.

The pure oil of *E. globulus* contains from about 50 to 65 per cent. of eucalyptol, and is regarded as the most valuable of the commercial medicinal oils.

On the other hand, the oil of *Eucalyptus amygdalina*, which was once greatly valued, contains not more than 25 per cent. of eucalyptol, and at the present time fetches only about two-thirds of the price of the *globulus* oil.

A third type of eucalyptus oils include those which have little or no medicinal value, but have a fragrant aroma and are used in perfumery and for scenting soap. Of these mention may be made of *Eucalyptus dealbata* of New South Wales, *E. citriodora*, the oil from which fetches four times as much as the medicinal oils, and *E. odorata*, which yields an odorous oil, used by soap makers in Australia.

The active constituent of the medicinal oils, *eucalyptol*, may easily be separated in a crystalline form, and is now a recognised commercial product, which is sold at about twice the price of the pure oil.

Eucalyptus oil is liable to be adulterated, and the pharmacopœial oils may be blended with other *Eucalyptus oils* poor in eucalyptol, or with oil from which part of that compound has been extracted.

Cajuput Oil.—This oil resembles eucalyptus oil in

containing a high proportion (about 65 per cent.) of cineol (eucalyptol), and to this must be attributed its value as a therapeutic agent. It is obtained by distillation of the leaves of *Melalenca leucadendron* or of *M. Minor*, shrubs growing abundantly in the Malay peninsula. The commercial oil has a camphor-like odour and is frequently of a green colour, due to the use of copper stills, but redistillation furnishes a colourless product.

Cajuput oil is official in the British Pharmacopœia. It is sometimes adulterated with turpentine, and is also liable to be sold deprived of part of its original cineol.

Volatile Oils Used as Solvents

Although many of the essential oils are good solvents for resins and other substances, few of them are used commercially for this purpose, since they are more profitably employed in other ways. The volatile oils obtained from the wood and resin of various species of pine and sold as turpentine oils are the chief representatives of this group, although of late years the residual *terpenes* from the manufacture of terpeneless oils, and the light oils left after abstraction of the safrol from camphor oil have been put to a similar use.

Oil of Turpentine.—Turpentine is a resinous exudation from the wood of trees belonging to the *Conifera*, or fir family, and consists of a mixture of resin (*rosin*) and a volatile oil, known commercially as *oil of turpentine*, *turps* or *terps*.

The crude turpentine is collected in the United States, largely by coloured labour. The trees (*Pinus australis*), locally termed the *yellow pine*, are subjected to the process of *boxing*. This consists in cutting a cavity or *box* a little above the root, and stripping the bark above this so as to form a channel for the exuding juice.

The incisions are made about the middle of March and the flow of turpentine continues until about the end of October. Each box holds from 1½ pints to over half a gallon, and is emptied several times during the season. The deposit left upon the back is known as *scraping*, and is collected towards the end of the season.

The crude turpentine from the *boxes* is mixed with about a quarter of its volume of water and distilled in copper stills. The distillate consists of a mixture of water and the essential oil of turpentine, while the residue in the still is the ordinary rosin or colophany of commerce. The oil is drawn off from the surface of the receiver, and is rectified by redistillation with a solution of caustic potash. The resulting product is the commercial *rectified oil of turpentine*, but to obtain a pure oil for medicinal purposes yet other distillations with water and over calcium chloride are necessary.

Purified oil of turpentine is a colourless limpid liquid with a characteristic odour and a burning taste. It is nearly insoluble in water, but mixes readily with fixed oils, and is itself a good solvent, for the substances used in the manufacture of varnishes. It burns with a dense smoky flame, at a relatively low temperature.

When exposed to the air it becomes yellower and assumes a more resinous character.

The American oil of turpentine, the bulk of which is obtained from the Georgia and "loblolly" pines (*P. Australis* and *P. tæda*) is regarded as the most valuable of the commercial varieties. The French oil (from *P. pinaster*) and the German oil (from *P. sylvestris* and *P. picea*) are recognised commercial products, which are sold at a lower price.

The Russian and Swedish oils of turpentine, derived from the oleoresin of *P. sylvestris* and *P. ledebourdii*, have an unpleasant odour, which reduces their

commercial value. Of late they have been subjected to refining processes to remove this odour, and the resulting products are sold under various names. They differ considerably from American turpentine oil both in physical and chemical characteristics. The Russian oil, in particular, has a much more irritant action upon the skin than the American oil.

The commercial *spruce turpentine*, which is obtained from *P. glabra*, closely resembles the ordinary American product.

In addition to these oils, *wood turpentine* is now prepared on an extensive scale in America, by distillation of the wood and stumps of the spent trees, whence the origin of its local name of "stump spirit." This oil is of much less value than the true *box* oil of turpentine, and is widely used to adulterate the latter. It is not unlikely that the change in the chemical characteristics of American turpentine oil, which has been noticeable during the last few years, is largely due to the common addition of wood turpentine.

Other adulterants of box turpentine oil are the more volatile portions of petroleum oil and mixtures of various terpenes from other essential oils. Various turpentine substitutes consisting of mixtures of this nature are on the market, and are used in paints and varnishes and in the manufacture of floor polishes.

PART III

MINERAL OILS

It is strange to reflect for how many ages the world was almost entirely dependent for its artificial light upon crude lamps, in which animal and vegetable oils were burned, or upon tallow or wax candles.

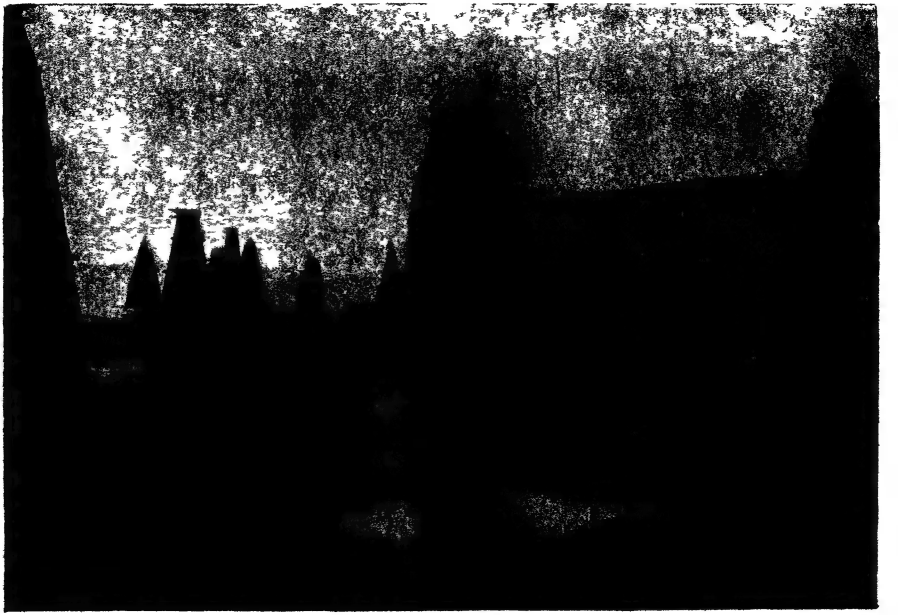
It is true that coal gas had then been introduced into many of the larger towns in Europe, but, for the most part, the houses were still illuminated by the primitive methods that had been in use for centuries.

The poorest class of people had to content themselves with such devices as pine-splint torches, feeble rush lights, or the flickering light from a fire.

Among Eastern nations the crude natural naphtha or petroleum which found its way to the surface through various fissures, or was obtained from shallow wells, had been used from time immemorial for burning in lamps, but the flame was usually smoky and the smell of the burning oil extremely disagreeable. The modern methods of refining petroleum oil so as to remove these drawbacks had not suggested themselves, and the abundant oil supplies in the United States still awaited discovery.

Thus the rise of the modern petroleum industry supplied a need long felt, since it furnished a cheap source of light in remote places where a supply of coal gas or (later) of electricity was not available. It completely displaced the use of the old-fashioned lamp, and enormously reduced the consumption of candles.

At the present time in this country the only vegetable



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LORD ROTHSCHILD'S LARGE FOUNTAIN AT BIBI-EIBAT

oil still employed for lighting purposes to any extent is colza oil, which is used for bicycle lamps or to shed a dim light in the carriages on certain railway lines.

The story of the rise and growth of the now gigantic petroleum industry is one of the most fascinating in the history of commercial products.

Origin of Petroleum.—The crude petroleum oil which issues from fissures in oil-bearing strata, or is carried forth by water springs, or is obtained by digging pits or sinking wells, is usually a light yellow or dark-coloured liquid with an unpleasant odour.

Chemically it consists of mixtures of impure compounds of carbon and hydrogen termed *hydrocarbons*, which boil at different temperatures, so that the oil may be separated by distillation into different fractions, the heavier of which are used for lubricating purposes while the lighter are used for oil engines and as lamp oils. To the same class of compounds belong the solid petroleum products (paraffin wax and the like) and the natural gas that accompanies petroleum.

There has long been controversy with regard to the origin of petroleum and the weight of many illustrious names has been given to the opposing theories.

According to the chemical theory, which was propounded by Berthelot, the petroleum hydrocarbons are the result of the direct union of the elements carbon and hydrogen, and this conclusion is supported by the fact that oils of the same kind have been experimentally produced in the laboratory.

There are, however, numerous difficulties in the way of accepting this view, and the organic theory is therefore more generally held. This attributes the formation of the petroleum deposits to the decomposition of animal or vegetable remains, which results in th formation of solid asphaltic or bituminous substance

or liquid petroleum oils or of gases. It is probable that animal life has played a greater part in the petroleum formation than vegetable life; but on this point, too, there is still much controversy, an interesting summary of which is given by MM. Neuburger and Noalhat.

Assuming that petroleum is of organic origin, the differences observed in the natural products would be accounted for by differences in the conditions, such as the degree of pressure, and nature of the strata in which the deposits were formed.

It was at one time believed that petroleum was produced at the same time as coal, and this led to the name of *coal oil* being given to petroleum oils. Yet, although an oil is obtained by the distillation of coal, it is quite distinct from petroleum oils, and in fact the petroleum deposits all over the world are found in a different class of rocks from those in which coal seams occur. The idea gained ground, however, from the fact that the first great petroleum deposits in the United States were discovered in districts which were already well known as coal-producing areas.

In most localities the oil is found deposited within underlying strata, which consist of porous material, such as sandstone or limestone, and may absorb more than a tenth part of their volume of the oil (Redwood).

The occurrence of pockets in the stratification also plays an important part in the accumulation of the petroleum, since the hollows thus left beneath the contorted shale become filled with oil.

As a rule the oil stored up in these different kinds of natural reservoirs is confined under pressure, which is probably caused by the accompanying gases. Hence, in boring a fresh petroleum well, it is no uncommon sight for a stream of the oil to be flung up into the air, and for a steady flow of thousands of tons to

continue from day to day, until the gas-pressure has been reduced.

The solid petroleum products such as bitumen and asphaltum, which occur as deposits in most parts of the globe, are probably the result of the natural oxidation and partial evaporation of petroleum oil which has found its way to the surface and has remained exposed to the air. The naturally occurring earth wax, commercially known as *ozokerite*, belongs to the same group of substances.

Similar solid paraffin waxes and pitches are obtained in the refining of crude petroleum oil.

Historical Outline.—Prior to the birth of the American and the Russian petroleum industry the use of the oil was almost entirely restricted to the inhabitants of the productive areas. Petroleum products were certainly known, however, at a very remote period. Thus, bituminous substances were employed by the early Egyptians and Babylonians for making pitch and similar purposes, and numerous references to their use may be found in the Old Testament.

Early Greek and Roman writers make frequent mention of bituminous deposits, and Herodotus (VI, 119), in particular, has an interesting passage describing a black evil-smelling oil which was obtained from wells in Persia.

Certain petroleum wells at Agrimentum are also described by Roman writers, and the oil from these was used there as a lamp oil upwards of 2,000 years ago.

At a later period oil was collected from wells near Modena, and still later, at the beginning of the nineteenth century, Genoa was lighted with lamps burning the crude oil. Some years afterwards a distilled oil is said to have been used for lighting the city of Prague (Redwood).

In other parts of Europe petroleum deposits have long

been utilised locally for lubricating purposes, while the oil discovered in various localities was usually put forward as a valuable medicinal remedy.

The most celebrated ancient wells are those in the region of Baku on the borders of the Caspian Sea. Here the deposits of petroleum occur so abundantly, and there is such a constant emission of the natural gas from fissures in the rocks, that it is easy to imagine how Baku became celebrated for its "eternal fire" and to understand why from times of remote antiquity it was the objective of fire-worshipping pilgrims from Persia and India.

The oil from the Baku springs was also celebrated, and expeditions were made from far-distant lands to secure supplies for burning in the temples at home.

The first attempts to develop the petroleum industry in Baku, however, date to the period when the district was annexed by Russia, about the beginning of the eighteenth century. The wells were then worked more or less systematically, and arrangements were made for the distribution of the oil by boat.

With the restoration of Baku to Persian rule this activity ceased, and it was not until the beginning of the last century, when the Russians again had control of the district, that the industry began to develop. Even then, and for long after the rise of the American petroleum industry, the export trade was neglected, and it is only recently that Baku has adopted modern methods and has become a dangerous competitor of the Americans.

The Chinese and Japanese records show that petroleum oil was known and was used as a lamp oil and for cooking as far back as the sixth century, while in India the working of petroleum springs dates back to the remote past. In Japan the oil is now produced and purified

by the most modern methods, but the industry is still relatively insignificant. Rich deposits are now being worked in various parts of Central and South America, in India and in Burmah, and surface indications show that in South Russia and many other regions of Asia there are hidden supplies of petroleum ready to take the place of the wells of to-day.

The American Industry.—The beginnings of the gigantic American industry attracted scant attention. From time to time attempts had been made to utilise the oil from the natural petroleum springs, but not until the nineteenth century had well advanced were any definite experiments made with it for lighting purposes. It was soon discovered that the crude product burned with a smoky flame and had a nauseous odour, and the oil was again relegated to its former employment as a quack medicine. The following graphic details of the first rush for oil are given by the French writer de Fonvielle (*Le Pétrole*, Paris, 1888).

About the year 1840 lamp oils were obtained on a commercial scale by the distillation of shale or coal, and were introduced into the American market under the name of *Kerosene*. The success of these coal oils suggested the possibility of purifying the crude petroleum oil by distillation, and some years later a distilled oil was obtained from petroleum, and found a ready sale. The supply of petroleum oil for this purpose was at first obtained by skimming it from the surface of the liquid in brine pits or wells, but soon afterwards special wells were drilled for the purpose in Pennsylvania. The first company was then promoted, and in 1859 the ingenuity of its engineer, Drake, to whom is due the method of driving an iron pipe through the sands and working the drill through the pipe, solved the problem of obtaining a plentiful supply of oil.

Fast upon the news of Drake's well came a period of wild excitement and mad speculation. Sites in the neighbourhood of Drake's well were sold for enormous prices, wells were drilled in every direction, mushroom companies were formed, and enormous fortunes were made and lost in a day. In a few weeks, quiet pastoral scenes were transformed into bustling mining camps, and the calm of ages was broken by the ceaseless din of machinery.

At first the wells were only sunk to the depth of about 80 feet, but in 1861 borings were made to a depth of 400 to 500 feet with the object of obtaining a still greater supply. Thus was discovered the first example of the type of wells which were aptly termed " spouters " or fountains.

The news of this discovery produced an immediate increase of frenzied excitement. In every direction deep borings were made, and in some cases flowing wells yielding thousands of barrels daily were discovered, and soon the output of oil became so plentiful that many of the smaller wells were rendered unprofitable.

In some areas the wells were so quickly exhausted that the districts were abandoned and once more given over to agriculture. Pithole City, for example, which in 1865 had burst into existence as a thriving city of 16,000 inhabitants, had been abandoned by the beginning of 1866, and had completely disappeared a few years later.

But with each fresh discovery of new oil fields there was a similar rush for riches with its usual accompaniment of speculative and fraudulent companies, followed by periods of depression and ruin brought about by over-production and consequent low prices.

Whatever criticisms may be brought against the powerful " trust " organisation controlling the production

and distribution of the oil, and including in its corporation nearly all the principal oil refiners in the United States, its formation has at all events prevented these periodical suspensions of the output of oil.

The Petroleum Well.—Apart from the relatively small amount of oil which exudes to the surface of the earth from the subterranean deposits, the world's supply of petroleum is derived from artificial wells.

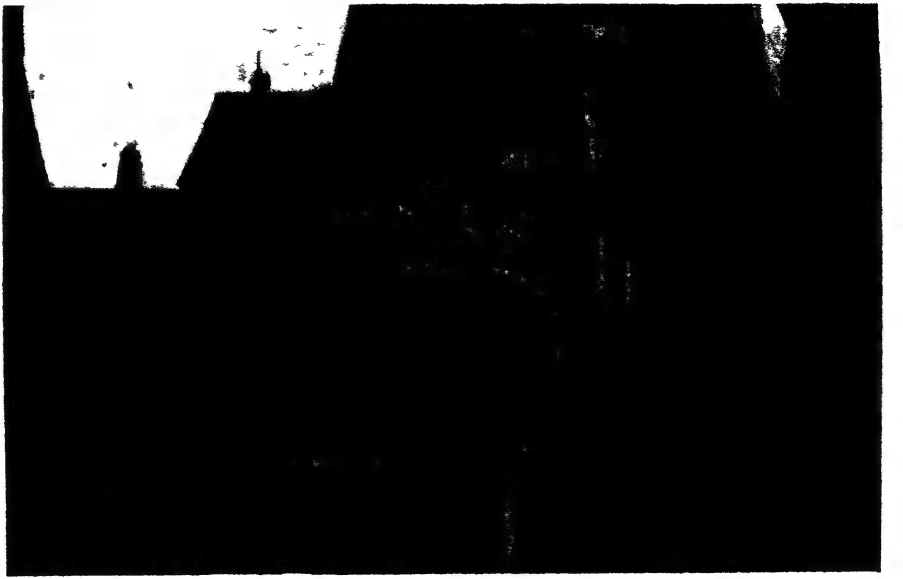
The occurrence of oil deposits is often indicated by certain surface signs, such as the formation of oil lakes, but it is largely a matter of chance whether the borings at any given spot within this area will prove successful. Thus, the well may prove not worth the labour of pumping, or it may be a fountain whence at first issue thousands or even millions of gallons of oil a day. Thus, in September, 1909, a fountain was struck in the Maikop fields in South Russia, from which issued a deluge of oil estimated at 30,000 tons in a week.

The modern method of drilling the wells is to sink an iron pipe down to the rock, and then to work the drilling tools within this pipe.

Two methods of drilling are in use—the American system, in which the drill is suspended by a wire rope from a derrick and is actuated by a moving beam worked by an engine, and the Canadian system, in which the drill consists of a series of iron or tough wooden rods ending in a large auger.

In wells of moderate depth the drilling may be finished in less than a month, but in the very deep wells, some of which may go down as far as 4,000 feet, the well may take a year to complete, especially if any accidents happen to the drill, necessitating tedious "fishing" for the broken bits.

A more rapid method of sinking the well is that known as Leschot's method. In this process the drill is made



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OIL WELL BEFORE THROWING UP OF SAND BY SPOUTING

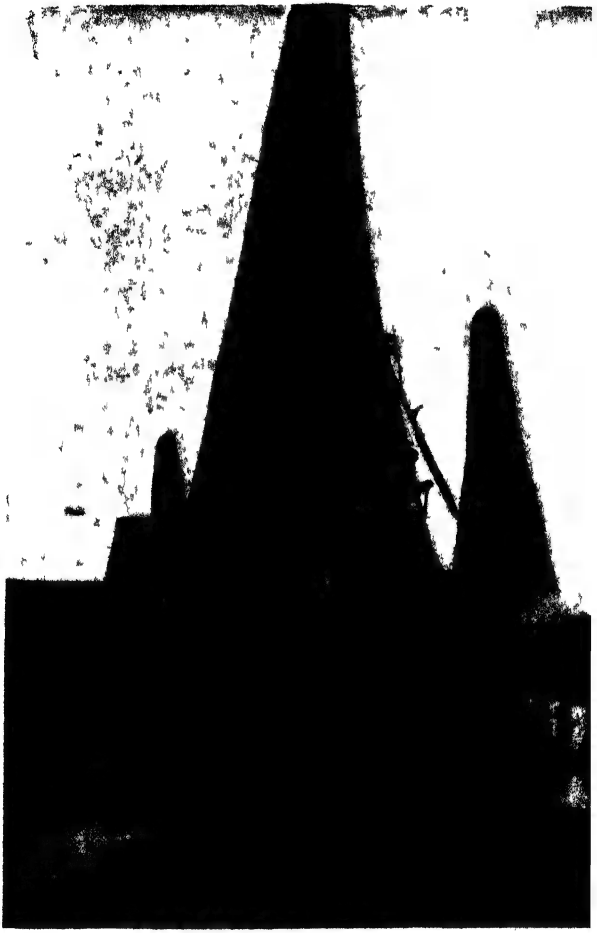
in the form of a hollow-jointed rod ending in a point of diamond, iridium or hard steel, which when working is kept cool by means of a current of water passing through the inside of the rod and issuing near the crown.

Sometimes in drilling for petroleum the drill strikes upon a supply of the oil confined under pressure, and then, without warning, the tools may be violently flung out of the boring and followed by a dense column of oil shooting two or three hundred feet up into the air and running to waste.

In America the most celebrated of these gushing or flowing wells have been found in Southern oil-fields, but they have been altogether surpassed in magnitude by some of the fountains at Baku.

But, however titanic the initial outburst may be, the supply of oil steadily diminishes, and eventually the well must become dry. This stage may be accelerated by the presence of neighbouring wells, which, drawing their supply from the same strata, tend to starve each other. Hence when once a well has been bored, the work of collecting the oil proceeds as rapidly as possible. Any stoppage means a present of so much oil to the other wells, such as happens with water in the case of adjacent artesian wells in the London area.

With the object of obtaining an increased yield of oil from poor wells, or of promoting the flow of oil in a well that has begun to give a diminished supply, resort is frequently had to the "torpedo." This consists in introducing a heavy charge of nitro-glycerin or other high explosive, and exploding it at the bottom of the well. Immediately after the dull report a stream of water and oil, carrying with it sand and fragments of shattered rock, is flung out of the well, to the height of a hundred feet or more.



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OIL WELL, SHOWING SAND THROWN UP AFTER SECOND DAY'S SPOUTING

This practice results in a quickened flow of oil, and in some cases it may be successfully repeated two or three times during the life of the well.

Even in the case of the most prolific flowing wells the natural outpour of oil ceases sooner or later, and pumps must then be used. The pumping process is often carried out by means of a central engine, which works the pumps in a large number of different wells, a great saving being thus gained over the older method in which each well had its own engine.

During the first quarter of a century after the beginning of the American petroleum industry, the crude oil was pumped into wooden tanks or earthenware reservoirs, and was generally refined in the neighbourhood of the wells. Open trenches for conveying the oil to the storage tanks were in common use, and contributed largely to the outbreak of the destructive fires which were of frequent occurrence in the oil-fields.

At the present time the risk from fire has been enormously reduced by the general adoption of the system of pumping the petroleum into iron receiving tanks. From these it passes by way of controlled valves into surface pipes communicating with a main line underground pipe, which conducts it directly to the refineries at New York, Philadelphia, and other places near the sea-board.

The pumping stations, which are provided with pumps capable of dealing with 30,000 barrels of oil a day, are placed at distances about forty miles apart.

Storage capacity is still essential on the oil-fields, for it frequently happens that the works are unable to deal at once with the huge output of oil from some of the wells. For this purpose there are provided huge iron tanks each capable of receiving hundreds of thousands of gallons of oil, and the area set apart for storage

may contain many dozens of such tanks. This arrangement enables the work of pumping the well to continue without intermission.

The advantages of pipe lines for the rapid transmission of the crude petroleum for hundreds of miles are so manifest that the system has been adopted in many other oil-fields, and at Baku, in particular, there is now a huge network of pipes to convey the petroleum to the refining factories placed near the points of distribution.

Distillation of Petroleum.—Reference has already been made to the drawbacks that prevented the general use of crude petroleum as a lamp oil, and to the fact that it was found possible to obtain a more satisfactory product by distilling the crude oil and separating the most suitable fractions of the distillate.

Although distillation had frequently been tried upon a small scale long before it was introduced as a commercial process, it was not until 1820 that iron stills were built for the purpose at Baku, and another thirty years passed before distillation suggested itself as a means of rendering American petroleum fit for burning in lamps.

The refined oil first produced in America was put upon the market under the name of "carbon oil." Great quantities of it were distilled in the plant which had originally been erected for the distillation of shale and coal, and the owners of which were threatened with ruin when it was discovered that similar distilled oils could be obtained more cheaply from petroleum (Redwood).

At first these oils found a ready sale, but as they still contained impurities which gave off an objectionable odour when burned, and caused charring of the lamp wick, their advance in popular demand was very slow. From the time, however, that it was found

that refined lamp oils free from these drawbacks could be obtained by subjecting the distillates from the crude petroleum to chemical treatment, the success of the petroleum oil industry was assured.

In the process of refining, the crude oil is first distilled in immense iron cylinders, which are heated by means of fires, and the vaporised products are conducted through long coils of pipes, which are chilled outside by a constant current of cold water. In these pipes the vapours are reconverted into the liquid state, and the distillates issuing from them are collected in different receivers.

As the constituent hydrocarbons in petroleum oil boil at very different temperatures it is possible to effect a separation of the original substance into fractions which differ from one another in density, and in the temperature at which they ignite.

In the *intermittent process* of distillation the oil is distilled in one still under successively increasing temperatures, while in what is known as the *continuous process*, the oil is pumped through a series of stills, each of which is heated at a temperature somewhat higher than its preceding neighbour.

The details of the distillation vary according to the nature of the products required. Thus, when a large yield of illuminating oils is desired, the following process is used. After light petroleum oils of the naphtha type have passed over, the temperature is raised, and the distillate, now consisting of illuminating oils, is directed into another receiver. When the bulk of this fraction has been collected the "cracking" process is used. This consists in allowing the next portion of the distillate to fall back into the still, which has meanwhile been heated to a somewhat higher temperature. The denser oils intermediate between

those of the illuminating and lubricating type are in this way decomposed into less dense compounds, which when now allowed to pass into the condenser have the characteristics of oil of the illuminating type.

After as much lamp oil as possible has been obtained, the distillation is stopped, and the residual tar in the still transferred, together with similar tarry residues from other stills, into another still, where the whole is fractionated further into heavy oils, paraffin wax, and a final residue of tar and coke.

In another process, to obtain more lubricating oil, the crude petroleum is distilled in the same way as far as the "cracking" operation, but the distillate is then carried into a second receiver, and not having been decomposed by falling back into the hot still, will consist of denser oils of the lubricating type. Another difference between these two methods is that in order to obtain as large a yield as possible of lubricating oils the distillation is assisted and rendered more regular by the introduction of a current of superheated steam into the still, in addition to the source of heat outside the still. The amount of residue which is left in this process is considerably greater than in the other process, and is subsequently worked up into heavy lubricating oils, paraffin wax, and coke.

In the continuous process of distillation the oil is passed from still to still, each of which, being heated at a constant temperature, furnishes a distillate of constant character. The yield of illuminating oils is smaller than with the intermittent process, but, on the other hand, the greater proportion of residue left in the stills is an advantage, since it fetches a high price as fuel.

Chemical Purification.—Although the distillates obtained by these processes are much better suited for

commercial purposes than the crude oil, they still require much purification before they can be sold.

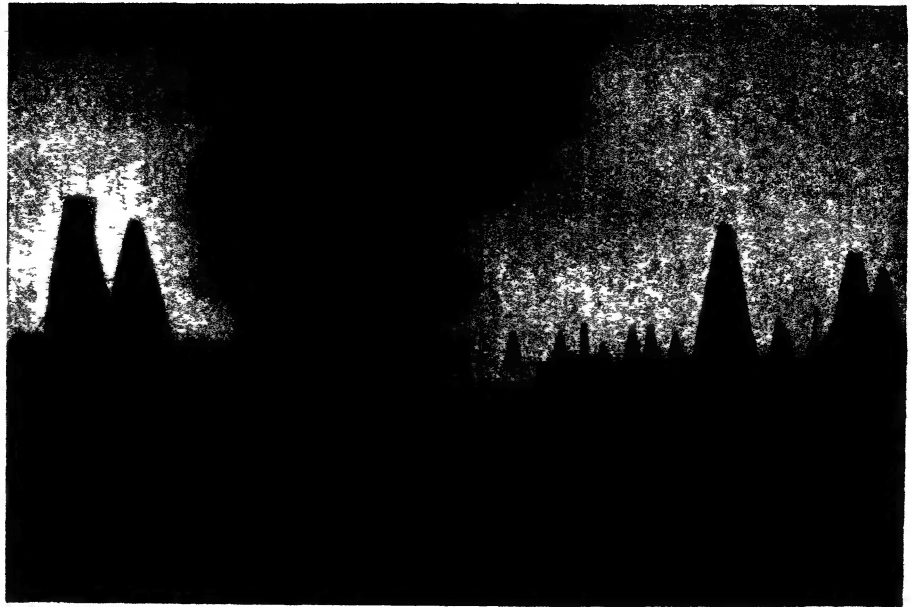
It is absolutely essential that all sulphur should be eliminated from petroleum distillates, and in some works this is effected by treating them first with sulphuric acid, then with caustic soda, and finally with litharge, which reacts with the sulphur, fixing it as insoluble lead sulphide.

Generally the light fraction, consisting of naphtha, is chemically treated and then redistilled in a steam-heated still, and thus separated into three grades, which are termed "gasoline," "commercial naphtha," and "benzine."

The kerosene fraction from the first distillation also requires considerable purification before it is suitable for burning in lamps, and is therefore treated in a similar manner to the naphtha fraction, and graded into different qualities. The purest of these is almost entirely free from the traces of the tarry and other impurities, which, in an imperfectly purified oil, cause the wick of the lamp to char and emit a disagreeable odour on burning.

The heavier fractions of the first distillation are worked up into lubricating oils. They are purified by chemical treatment and for certain purposes are also bleached and filtered, and the products are graded according to the purposes for which they are required, the lightest oils being known as "spindle oils," and the heaviest consisting of "heavy machine oils."

In addition to the machine oils prepared by distillation, a certain amount of lubricating oil is also made from special kinds of crude petroleum by a process of "sunning," which consists in exposing a light oil to the air in an open vessel, so that as it evaporates spontaneously a denser product is left. This concentration



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NOBEL'S LAKE ON FIRE AT BALAKHANY

is also accelerated in some cases by the aid of a slight application of steam, the oils being then termed "reduced" oils.

Finally, the residues left from the last distillation are distilled at a high temperature in steel stills of special construction, the last fractions of the distillate consisting of paraffin wax in a relatively pure condition, while the residue consists of pitch or asphaltum. The wax is freed from water, and then cooled by means of ammonia refrigerators, which cause it to become solid, after which as much of the retained oil as possible is expressed in a filter-press. The solid mass is now melted once more, and decolorised by filtration through animal charcoal, and is finally allowed to crystallise and pressed into compact blocks in a hydraulic press.

The proportion of these different purified products varies considerably with the nature of the crude petroleum and the treatment. Thus, an oil may yield as much as 80 per cent., or as little as 20 per cent. of illuminating oils, while the yields of lubricating oils may range from nothing to about 25 per cent., and that of the coke or asphaltic residues (including waste in working) may be as high as 28 per cent.

Testing Petroleum Products.—The different classes of oils refined by methods such as those described are all subjected to special tests before being put upon the market. In particular it is essential that the kerosene oils intended for lamps shall be free from fractions of the distillate that give off inflammable vapours at a low temperature.

For this purpose what is known as the "flashing-point" is determined. This consists in heating the oil gradually and under constant conditions in a special apparatus in which is a thermometer, and applying a light from time to time to the vapours expelled by the

heat. The temperature at which these ignite is the "flashing-point."

The light naphtha fractions, including benzoline and petrol, give off inflammable vapours at very low temperatures, and as these form explosive mixtures with air it will be readily understood how a small proportion of such compounds in lamp oil has been the cause of innumerable fatal accidents.

Prior to the recent rapid development of the motor industry and the consequent demand for petrol, there was less commercial inducement to free the kerosene oils completely from the fractions of lower boiling point, and hence many of the cheaper grades of paraffin oils were dangerous to use. In some countries the flashing-point was legally fixed at temperatures that were barely sufficient to ensure safety, even when lamps of proper construction were used, and oils were frequently put upon the market that were far from giving even this minimum of security against explosion. At the present time the value of the light naphtha fractions is in itself a safeguard, since care is now taken to separate them more effectually from the kerosene fractions, and in consequence cheap illuminating oils are much safer than was the case a few years ago.

The chief requirements, apart from a low flashing-point, of a good lamp oil, are that it shall be free from acid and sulphur, and that it shall be colourless, or nearly so. The presence of acidity, left from the refining process, is objectionable, since it causes charring of the wick in the lamp, while sulphur compounds give off an obnoxious odour when burning. The degree of colour affords a rough indication of the amount of impurities in an oil, and refined oils are classified into various grades, according to their position in the colour scale.

Thus, in the American trade the best product is known as *water-white* kerosene; then comes *prime white* kerosene, and *standard* kerosene, the colour of which is distinctly yellow. These descriptions are also in common use for recognised qualities of oil in this country.

In testing lubricating oils the most important points to be determined are the viscosity and the behaviour under heat and cold. The viscosity, or in other words, the speed at which an oil will run through a small opening, is usually determined in a special apparatus and the result compared with that given by water or by rape oil in the same apparatus and at the same temperature.

The particular temperature at which the test should be made will obviously depend upon the use for which the oil is intended. Thus, a lubricating oil for the cylinders of a marine engine is tested at a very much higher temperature than an oil to be used for lubricating cold machinery.

Another method of testing the mobility of a lubricating oil is to cause a small metal disc to revolve by means of clockwork within the oil, and to count the number of revolutions made in a given time under standard conditions of temperature and driving power.

The flashing-point of engine oils is also a matter of great importance, as it is essential that no inflammable vapours should be given off at temperatures to which the oil would be likely to be subjected during the working of the engine.

Again, since a lubricating oil may be subjected to low temperatures, it is necessary to determine at what point it becomes turbid or congeals. The best qualities of cylinder oil are expected to remain fluid at temperatures between 50 and 60° F. on the one hand, and on the

other hand to be capable of being heated to high temperatures without giving off inflammable vapour.

It is also imperative that lubricating oils should not contain the slightest trace of mineral acid, since otherwise rapid corrosion of the bearings, etc., of machinery may result. The proportion of tarry and coke-like substances in an oil is a further important factor in determining its suitability for certain purposes, *e.g.*, turbines; and methods are now employed to determine the amounts of those substances that would probably be formed in practice. The smaller the proportion of tar and coke formed in an oil after having been exposed for some time at a high temperature, the better the quality of the oil.

In addition to the foregoing tests determinations are made as to the "gumming" tendency of an oil, or in other words, its liability to become viscid and sticky after having been in use for some time. This change is due to the absorption of atmospheric oxygen. Hence the measurement of the rate of absorption of free oxygen affords a useful measure of its "gumming" tendency.

For instance, in a comparative experiment a sample of a mineral lubricating oil absorbed only 0·7 per cent. of oxygen in ten hours at a high temperature, whereas cotton seed oil under the same conditions absorbed 171 times its weight of oxygen, and became so viscid that it would have been useless as a lubricant.

Naphthas.—The light products of distillation at the other end of the scale to the heavy lubricating oils are tested as to their freedom from acidity, and are graded in accordance with their boiling points, and specific gravity. Their ready volatility and power of forming explosive mixtures with air are utilised in driving petrol engines of every description.

Paraffin Wax.—The higher the solidification point of paraffin wax the greater its value for candle-making, and accordingly paraffin waxes are tested and graded in accordance with the temperatures at which they melt and become solid again.

It is commonly accepted that a transparent wax is of better quality than an opaque wax, for manufacturers regard transparency as a proof that the oil has been completely expressed from the wax. This belief, however, is not borne out by experimental results, since it is quite possible for transparent and opaque samples of wax to contain approximately the same amount of oil.

Oil from Natural Gas.—During the last few years many ingenious methods of meeting the demand for light petroleum spirit have been tried. The most successful of these has been the condensation of part of the natural gas emitted from the oil-wells in America and Galicia.

The gas is collected and passed through compressors, where it is fractionally compressed at pressures ranging from 17 to 20 atmospheres, and at temperatures below 32 deg. F. The richest gas found in America usually yields from 40 to 46 litres of gasoline per 100 cubic metres. The compressed liquid is colourless or light brown, and has a specific gravity ranging from about 0·650 to 0·770.

Some of the compounds in the natural gas are only just liquefiable under these conditions, and afterwards evaporate when exposed to the air under normal conditions, thus causing a loss of spirit. These are technically known as "wild products." The residue of uncondensable or "exhaust gas" from the compressors is used to drive engines or heat stills, or is sold to the gas companies for lighting purposes.

The condensed gasoline is officially known as *liquefied petroleum gas* in the United States, and must have a lower vapour pressure than 10 lbs. to the square inch, at 90 or 100 deg. F., according to the time of the year. It is said to have given good results when used by itself in motor engines, though it has been known to cause troubles through its want of homogeneousness. It is, however, more generally mixed with the lighter fractions from the refineries.

According to the published statistics, the total production of gasoline from natural gas in the United States in 1911 was 7,425,839 gallons by 176 works. In 1912 the output had risen to 12,081,179 gallons from 250 works, while in 1913 the production exceeded 16,000,000 gallons. The market price ranged from 5d. per gallon in the Gillcrease district to 7d. to 9d. per gallon in California.

The gas from the Galician oil-fields gives a very much lower yield of gasoline than the American natural gas, and with petrol at a normal price hardly repays the cost of condensation.

Uses of Petroleum.—In addition to their use as illuminants and for driving and lubricating engines of various kinds, there are many other directions in which petroleum products are of service to mankind.

Thus, in medicine, the semi-solid petroleum derivative known as vaseline, petroleum jelly, etc., meets a long-desired want for a substance that would act as a vehicle for the active drugs in an ointment, while itself remaining relatively unaltered on exposure to the air.

Vaseline and deodorised paraffin oil are also used as the basis of many of the most widely advertised hair restorers. Employed in this way they probably have both a strong antiseptic action upon micro-organisms, while at the same time stimulating the growth of the hair.

It is largely to paraffin oil, also, that Sierra Leone, "the white man's grave," and the haunts of malaria all over the world owe the great improvement that has taken place in their formerly deadly conditions. The discovery that yellow fever and malaria were spread by the bites of particular species of mosquitoes was soon followed by attempts to stamp out the cause by destroying the mosquitoes while in the larval condition in ponds and stagnant pools.

Wherever it was not found possible to drain away the water, a thin layer of paraffin oil floated upon the surface proved an effectual means of destroying the larvæ.

Another important application of petroleum products is as a source of oil gas, a large proportion of which is derived from the so-called "gas-oils" obtained from the tar-stills. The gas from this source is of the greatest value for illuminating purpose in remote places such as light-ships, and it has also the merit of being readily compressible, and so easy of transport. Oil-gas is now frequently employed for lighting the carriages on railways. It is also added to poor coal-gas to obtain a product richer in illuminating hydrocarbons.

In the kerosene lamps used with incandescent mantles the oil is vaporised by heat and burned with an admixture of air so as to obtain an intensely hot non-luminous flame similar to the blue flame of a Bunsen gas burner. The kerosene vapour burned in these lamps differs from oil gas in the fact that, if cooled, it would become liquid again, whereas oil gas has to be subjected to considerable pressure before it liquefies at the ordinary temperature.

Petroleum products are also being used in increasing quantities for fuel, and being readily handled, as compared with coal, and having a greater heat-producing

capacity, they are particularly valuable for marine engines. The extent to which they are utilised for locomotives is shown by the fact that in 1907 the amount of oil consumed on the railroads in the United States was 18,855,691 barrels.

Wherever other kinds of fuel is scarce the use of petroleum fuel has been the greatest boon to industries of every kind. Thus, on the Baku oil-fields the residues from the still are burned to supply the heat for the distillation of crude oil.

The type of furnace now employed dates from 1865, when it was patented by Aydon Wise and Field. In this the oil is sprayed from a fine jet into the hot furnace, where it meets a supply of air in sufficient quantity to effect its combustion. The discovery of this process and the many mechanical improvements in the methods of admitting the spray of oil have had much to do with the growth in favour of petroleum as a fuel, and at the present time many oil-fields which yield oils of low quality little suited for illuminating purposes are profitably worked owing to the demand for oil as fuel.

The various paraffin waxes, which are now among the most important products of the petroleum industry, are used for many technical purposes. Those of higher melting point are employed in enormous quantities in the manufacture of wax candles, while the softer waxes are used in the preparation of floor polishes and as a neutral basis for ointments. Other uses to which paraffin wax is put include the coating of the interior of barrels, so that the liquid carried in them shall not extract colouring matter from the wood; the preparation of waxed paper; insulation of electric bell wires; the waterproofing of textile fabrics; and innumerable other purposes.

Even the residues in the stills, when not used for fuel

as in the Baku oil-fields, are worked up into serviceable products. Thus, chemical treatment of the tarry matter yields pigments of all colours, analogous to those derived from the coal tar of the gas works; while the coke when ground to a fine powder and compressed into sticks is utilised as the carbon for electric arc lamps.

The Future of Petroleum.—Fortunately the time is still remote when the problem of what is to take the place of petroleum products will become an urgent question, but it is none the less surely approaching. Whereas, in the case of vegetable and animal oils the supply is inexhaustible so long as life continues on the earth, the petroleum deposits on the other hand, were formed in ages past, and when once used up are not replaceable.

The history of the dead cities of the American oil fields pictured by de Fonvielle is a striking example of the sudden manner in which an abundant supply of oil may fail, and there can be no doubt that the same exhaustion awaits even the most prolific oil-fields of to-day.

Before the time of oil famine comes, however, there are vast deposits to be worked all over the world. It is probable that in America the richest deposits have already been tapped, but in Russia there are still immense areas as yet untouched, and it seems not unlikely that within a few generations the world's supply of petroleum products will be mainly drawn from the undeveloped oil-fields of Asia.

With the failure of the great oil centres of to-day, the numerous less important oil-producing districts in India, Canada, South America, Africa and other parts of the globe will receive more attention from the capitalists, and wells in the older areas that have been

abandoned owing to their scanty supply of oil will again be worked.

As to what will be done when the final period of exhaustion arrives, as it inevitably must, we can only hazard a guess. But whatever means may be discovered of filling the gap left by the failure of petroleum, it is unlikely that the world will ever again enjoy the use of a substance that may be utilised in so many directions.

APPENDIX

THE TRADE IN OIL

APPENDIX

THE TRADE IN OIL

Some idea of the magnitude of the trade that is done in oils may be gathered from the following table, which embodies figures published by the Board of Trade of the quantities annually imported into this country during the years 1898 to 1908.

Description of Oils.		1898.	1899.	1900.	1901.	1902.	1903.
Animal	cwts.	56,723	54,273	108,892	91,870	70,329	168,139
Castor	,,	125,800	118,052	53,335	107,297	122,843	92,137
Cocoanut	,,	307,101	458,297	552,743	478,143	495,860	782,632
Chemical, Essential and Perfumery ..	lbs.	1,893,405	1,620,234	1,758,331	1,941,207	1,772,688	1,424,046
Fish	tuns	20,673	20,358	21,323	24,384	23,470	22,141
Olive	,,	18,044	15,939	12,044	15,488	18,978	14,485
Palm	cwts.	910,900	945,472	938,350	1,212,111	1,446,298	1,234,004
Petroleum, Lubricating	galls.					38,880,752	44,356,789
,, Illuminating (Lamp)	,,						1,713,195
,, Spirit ..	,,	219,249,539	203,521,374	215,268,480	217,209,601	245,928,958	9,902,545
,, Gas ..	,,						5,361,181
,, Fuel and Other Kinds	,,						6,616,165
Seed Oils	tons	35,923	46,416	41,1	48,842	35,454	36,011
Turpentine	cwts.	573,089	495,808	595,4	643,846	532,455	533,109

Description of Oils.		1904.	1905.	1906.	1907.	1908.
Animal	cwts.	210,294	238,595	165,659	181,597	150,222
Castor	,,	60,881	61,787	50,329	50,391	317,741
Cocoanut	,,	615,238	613,165	335,545	35,781	555,335
Chemical, Essential and Perfumery	lbs	1,834,421	1,795,396	1,882,080	2,093,198	2,004,737
Fish	tuns	24,459	25,508	27,808	26,929	32,137
Olive	,,	150,101	7,690[1]	9,419[1]	7,391[1]	6,330[1]
Palm	cwts.	1,309,176	1,144,368	1,223,787	1,508,023	1,317,995
Petroleum, Lubricating	galls.	44,833,756	47,524,054	49,704,819	49,529,960	51,672,903
,, Illuminating (Lamp)	,,	177,550,084	157,265,095	151,239,979	150,611,230	168,349,458
,, Spirit ..	,,	119,972,459	186,583,391	26,792,687	33,536,739	41,807,995
,, Gas ..	,,	58,429,434	63,763,745	56,551,321	61,719,374	66,280,671
,, Fuel and Other Kinds	,,	9,345,410	12,899,050	1,493,801	8,737,179	15,502,021
Seed Oils	tons	10,553	3,309[1]	1,786[1]	1,111[1]	2,203[1]
Turpentine	cwts.	528,112	526,679	512,836	510,308	573,678

[1] Not including Refined Oil.

In the following tables are given the comparative quantities and values of the chief oils and fats imported and exported during the three years 1907 to 1909:—

IMPORTS INTO THE UNITED KINGDOM FOR THE YEARS ENDING DECEMBER 31st.

	1907.	1908.	1909.	1907.	1908.	1909.
				£	£	£
Crude Oils—						
Fish, Train, Blubber, Sperm .. .. tuns	26,929	32,137	36,221	529,947	601,041	637,221
Cocoanut .. .. cwts.	357,815	555,335	502,408	634,357	757,812	752,251
Olive .. .. . tuns	7,391	6,330	4,788	287,254	243,497	241,905
Palm .. .. .. cwts.	1,508,023	1,317,995	1,762,641	1,896,133	1,559,266	2,195,620
Refined Oils—						
Cocoanut .. .. cwts	118,903	203,077	177,085	223,522	323,334	315,690
Cotton Seed .. tons	14,226	15,251	17,560	365,512	401,506	482,139
Olive .. .. .. tuns	4,937	5,822	4,186	——	——	——
Palm .. .. .. cwts.	18,656	35,838	58,645	251,634	293,308	276,743

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		1907.	1908.	1909.	1907.	1908.	1909.
Butter	cwts	4,210,156	4,210,821	4,062,833	£22,417,926	£24,080,912	2,425,067
Margarine	,,	885,068	813,447	868,292	2,223,645	2,081,245	2,243,737
Lard, from U.S.A. ..	,,	1,903,961	1,924,881	1,703,578	4,491,539	4,407,410	4,857,199
,, from Other Countries	,,	61,170	62,610	56,707			
Imitation Lard ..	,,	222,090	174,064	231,847	408,192	306,700	438,909
Petroleum—							
Crude	galls	—	215,700	1,185,510	—	3,475	16,080
Lamp Oils	,,	150,611,230	168,349,458	146,817,883	2,551,297	2,894,395	2,294,606
Spirit (Petrol) .	,,	33,536,739	41,807,995	52,169,776	979,395	1,118,847	1,215,377
Lubricating Oils ..	,,	49,529 960	51,672,903	53,903,880	1,643,142	1,666,952	1,631,367
Gas Oils	,,	61 719,374	66,280,671	71,586,006	830,165	830,163	690,186
Fuel Oils ..	,,	8,737,179	15,286,321	32,687,326	88,286	148,979	276,273
Total ..		304,134,482	343,613,048	358,350,381	6,067,288	6,662,811	6,123,889
Turpentine . ..	cwts	510,308	573,678	443,375	975,166	838,454	699,807

EXPORTS FROM THE UNITED KINGDOM FOR THE YEARS ENDING DECEMBER 31st.

Description of Oils, etc.		1907.	1908.	1909.	1907.	1908.	1909.
					£	£	£
Crude Oils—							
Cocoanut ..	cwts.	56,058	56,887	61,247	95,074	79,653	89,327
Olive	tuns	—	26	70	—	1,341	3,915
Palm	cwts.	4,946	415	1,787	7,568	543	2,554
Refined Oils—		—	—	—	846,037	705,020	822,923
Butter	cwts.	12,305	10,045	9,214	68,591	59,324	54,805
Lard	,,	9,634	8,118	5,506	26,432	22,340	18,722
Imitation Lard	,,	568	583	792	864	1,008	1,604

From the year 1910 onwards greater differentiation of the classes of oils has been made in the Board of Trade returns, and certain products formerly classified under other headings are now grouped with the oils. The following tables give the quantities and values of oils imported and exported during the five years ending December, 1914.

IMPORTS OF OILS FOR THE YEARS ENDING 31ST DECEMBER.

Oil.	Quantities.					Values.				
	1910.	1911.	1912.	1913.	1914.	1910.	1911.	1912.	1913.	1914.
	Cwts.—					£	£	£	£	£
Animal Oils	105,571	181,679	206,659	224,324	192,134	146,654	243,420	280,693	298,026	262,969
	Tuns—									
Fish Oils, etc.	46,101	58,962	68,030	70,886	52,537	927,231	1,252,663	1,296,477	1,508,416	1,139,400
	Cwts.—									
Cocoanut (unrefined)	539,686	545,960	631,432	622,801	396,593	1,013,629	1,001,227	1,202,527	1,342,469	807,463
,, (refined)	500,219	588,897	601,757	546 742	309,417	1,136,736	1,259,083	1,327,955	1,316,246	739,902
Mineral jelly and Vaseline	21,773	20,654	26,147	19,626	23,418	47,960	46,831	60,553	45,322	56,122
	Tuns—									
Olive (unrefined)	6,905	4,424	9,611	2,882	5,577	299,922	200,619	386,239	130,191	266,563
,, (refined)	6,311	4,336	6,686	6,163	6,388	386,189	296,824	402,894	385,257	396,849
Palm and Palm-kernel	Cwts.—									
(unrefined)	1,994,385	1,630,726	1,646,474	1,562,203	1,487,765	3,056,614	2,473,200	2,375,530	2,326,842	2,257,645
,, ,, (refined)	60,775	111,545	43,944	58,230	62,399	111,800	223,777	90,335	141,967	138,364

IMPORTS OF OILS FOR THE YEARS ENDING 31ST DECEMBER—CONTINUED.

Oils.	Quantities. 1910.	1911.	1912.	1913	1914	Values. 1910.	1911.	1912.	1913.	1914.
	Galls—					£	£	£	£	£
Petroleum (Crude)	187,318	74,334	12,742	1,108,900	15,105,588	3,310	1,621	265	14,746	154,930
„ (lamp)	138,828,483	142,575,869	146,030,093	157,141,241	150,131,233	1,850,918	1,708,913	2,106,359	2,679,518	2,501,054
„ (spirit other than motor spirit)	239,948	5,680	80	270	——	4,872	801	4	46	——
„ (lubricating)	58,560,651	60,526,599	69,327,061	67,962,493	66,646,512	1,705,866	1,662,742	2,059,797	2,472,514	2,340,982
„ (Gas Oil)	57,507,131	58,008,508	73,273,526	65,949,677	83,105,346	477,704	417,310	635,689	735,388	977,234
„ (Fuel Oil)	34,363,276	33,074,138	48,135,845	95,062,187	212,675,855	262,455	230,960	426,187	1,149,816	2,479,336
„ (other sorts)	733,819	3,447,786	963,856	24,178	17,942	17,206	59,837	20,940	1,381	800
Motor Spirit	55,949,210	67,926,563	79,590,155	100,858,017	119,030,155	1,340,551	1,612,267	2,092,448	3,803,397	4,301,865
	Cwts.—		Tons—							
Castor	26,898	37,361	1,350	1,399	845	39,334	57,398	40,122	41,875	25,542
	Tons—									
Cotton-seed (unrefined)	902	3,557	6,168	1,070	3,114	22,984	98,129	168,852	31,748	89,851
„ (refined)	15,950	21,909	21,666	16,586	19,866	562,672	713,925	660,268	558,277	659,475
Linseed (pure)	37,242	28,847	30,860	11,866	5,152	1,252,141	1,170,165	1,128,224	310,157	129,190
„ (not pure)	1,221	287	117	88	104	25,477	9,527	3,747	513	2,442
Rape Seed	13,489	8,408	8,280	7,599	6,861	359,166	246,193	252,626	222,586	198,162
Other Seed Oils	12,455	12,526	14,890	20,380	24,314	398,597	440,334	555,679	767,810	868,001
	Cwts —									
Turpentine	472,247	480,130	656,216	560,330	348,206	1,001,216	914,028	1,028,007	768,800	542,205
	Lbs —									
Essential (natural)	1,983,063	2,027,094	1,929,286	2,323,348	2,286,696	320,218	379,150	419,779	555,376	532,915
„ (artificial)	169,599	136,887	198,441	260,638	141,257	34,369	25,889	36,368	35,613	21,025
Oils unenumerated values only	——	——	——	——	——	160,741	197,770	240,092	139,427	145,059
Edible Fats—	Cwts.									
Butter	4,325,539	4,302,692	4,005,159	4,139,028	3,984,204	24,493,450	24,600,617	24,354,193	24,083,658	24,014,276
Margarine	1,120,812	944,405	1,352,427	1,518,297	1,529,219	2,935,244	2,461,325	3,514,045	3,917,701	3,977,361
Lard	1,452,493	1,822,763	1,790,487	2,005,360	1,765,107	4,520,074	4,251,758	4,573,136	4,552,462	4,750,943
Imitation Lard	275,403	183,469	218,522	224,519	252,742	603,444	360,878	434,623	465,503	525,185

EXPORTS OF PRODUCE AND MANUFACTURES OF THE UNITED KINGDOM

Oils.	Quantities. 1910.	1911.	1912.	1913.	1914.	Values. 1910.	1911.	1912.	1913.	1914.
	Cwts.—					£	£	£	£	£
Cocoanut (unrefined)	73,173	39,387	77,503	62,067	50,837	126,710	72,794	142,978	127,465	105,709
,, (refined)	228,109	62,075	51,667	58,913	56,260	430,663	126,750	109,179	141,777	147,631
	Tuns—									
Olive (unrefined)	22	10	20	20	12	1,354	601	912	1,183	626
,, (refined)	368	300	310	304	228	49,125	41,982	44,052	45,487	36,552
	Cwts.—									
Palm (unrefined)	48,214	28,619	11,710	20,995	63,685	84,801	53,022	21,315	43,096	138,331
,, (refined)	13,710	8,782	13,965	15,168	20,153	23,458	14,518	21,359	24,169	39,264
				Tons—						
Castor	——	——	——	10,818	7,715	——	——	——	301,839	202,025
	Tons—									
Cotton-seed (unrefined)	411	337	540	522	438	11,979	9,317	14,962	15,453	13,198
,, (refined)	29,501	22,369	19,882	25,013	27,002	874,571	661,639	533,799	755,083	864,037
Linseed (pure)	21,463	23,583	22,348	26,738	22,513	837,712	1,050,856	895,318	794,150	639,986
,, (not pure)	3,021	3,340	3,565	3,173	1,832	98,854	120,838	123,294	86,683	48,389
Rape	5,052	6,205	5,479	5,839	6,830	141,368	187,140	170,269	175,846	206,192
Soya Bean	——	20,486	17,327	9,390	9,321	——	630,073	504,668	294,238	305,059
Other Oils	38,944	1,702	5,722	2,287	3,160	1,122,146	52,578	163,496	61,240	89,853
			Lbs.—							
Essential Oils	——	——	380,619	363,787	403,824	——	——	103,117	111,510	186,316
Edible Fats—	Cwts.—									
Butter	9,244	11,928	11,342	10,895	10,913	56,256	70,631	72,029	65,065	64,934
Margarine	71,778	36,125	26,663	25,712	18,942	176,930	93,570	78,731	75,066	55,693
Lard	5,611	10,337	9,680	6,179	10,042	21,142	30,429	30,818	21,902	32,494
Imitation Lard	2,741	3,589	2,796	1,964	753	6,616	8,255	6,358	4,605	1,804

EXPORTS OF FOREIGN AND COLONIAL MERCHANDISE.

Oils.	Quantities. 1910.	1911.	1912.	1913.	1914.	Values. 1910.	1911.	1912.	1913.	1914.
	Cwts.—					£	£	£	£	£
Animal	6,334	4,066	5,980	5,462	3,694	10,419	6,999	10,223	10,310	7,175
	Tuns—									
Fish	3,945	6,235	14,205	5,796	4,685	32,499	130, 72	270,841	121,360	99,216
	Cwts.—									
Cocoanut (unrefined)	112,692	62,240	67,424	6,0911	37,565	229,203	124,109	134,723	129,846	86,140
,, (refined)	9,364	10,388	16,292	11,581	12,481	20,464	22,321	38,513	27,917	32,425
Mineral Jelly and Vaseline	5,334	7,232	9,872	3,817	3,435	12,540	16,384	21,977	10,218	8,648
	Tuns—									
Olive (unrefined)	401	457	916	313	393	13,920	19,083	33,483	13,550	17,847
,, (refined)	734	627	1,023	813	817	53,713	46,460	82,373	70,689	63,705
Palm and Palm-kernel	Cwts.—									
(unrefined)	1,205,090	894,245	922,746	924,875	847,609	1,820,598	1,330,040	1,310,981	1,308,050	1,210,747
,, ,, (refined)	——	33	870	774	430	——	78	1,468	1,858	1,187
	Galls.—									
Petroleum (Crude)	19,276	86	100	——	——	340	7	3	——	——
,, (Lamp)	1,926,391	718,021	818,326	508,960	838,023	34,532	16,041	23,160	16,857	19,568
,, Spirit (other than motor spirit)	489,885	182	13,142	270	——	11,892	13	670	46	——
,, Lubricating	1,479,038	1,274,548	1,178,433	1,112,414	1,060,222	58,277	56,216	57,656	60,851	59,093
,, Gas Oil	1,174,993	970,411	1,326,607	614,470	2,110,996	18,357	15,681	17,344	13,038	27,742
,, Fuel Oil	89,746	485,016	379,502	1,181,271	750,140	1,250	6,635	5,145	19,261	11,813
,, Other Sorts	——	——	275,559	40	4,000	——	——	6,046	1	150

EXPORTS OF FOREIGN AND COLONIAL MERCHANDISE—CONTINUED.

Oils.	Quantities.					Values.				
	1910.	1911.	1912.	1913.	1914.	1910.	1911.	1912.	1913.	1914.
	Cwts.—		Tons—			£	£	£	£	£
Castor	1,159	1,172	40	31	10	2,142	2,246	1,909	1,674	428
	Tons—									
Cotton (unrefined)	61	33	1,258	174	432	1,316	914	37,874	5,699	13,679
,, (refined)	1,170	787	1,174	773	1,819	39,315	28,888	34,879	24,941	53,766
Linseed (pure)	763	193	504	881	123	25,747	8,014	17,618	21,819	3,400
,, (not pure)	——	——	——	——	9	——	46	——	10	295
Rape	93	157	65	3	39	2,624	4,682	1,858	161	1,239
Other Seed Oils	1,277	2,541	1,135	1,237	1,054	32,048	67,970	32,147	45,006	37,405
	Cwts.—									
Turpentine	19,591	20,227	23,816	23,140	24,760	37,380	46,498	39,862	36,462	40,061
	Lbs.—									
Essential Oils (natural)	624,560	654,735	733,724	701,598	495,616	80,110	88,697	113,456	142,821	115,898
,, ,, (artificial)	5,271	9,778	2,969	2,083	5,147	1,173	3,812	729	1,229	1,838
Unenumerated, values only	——	——	——	——	——	33,036	56,348	51,402	25,774	21,621
Edible Fats—	Cwts.—									
Butter	68,344	135,552	119,021	105,670	91,175	384,088	759,214	715,096	584,674	510,148
Margarine	7,024	10,400	5,953	8,175	8,757	17,420	23,488	16,474	21,693	23,272
Lard	119,457	204,098	227,730	304,826	171,685	383,907	504,984	580,021	865,450	483,639
Artificial Lard	4,652	5,790	3,384	5,171	4,398	10,815	12,416	7,676	11,237	9,437

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